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Kritische Erfolgsfaktoren für die Zulassung europäischer Industrieprodukte in Indien, anhand eines europäisch entwickelten und produzierten Produktes für die indische Rolling Stock Industrie.

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MASTERTHESIS

Critical success factors for the approval of European industrial products in India, based on a European developed and produced product for the Indian rolling stock industry.

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Die vorliegende Arbeit befasst sich mit der Analyse der kritischen Erfolgsfaktoren für die Zulassung europäischer Industrieprodukte in Indien, anhand eines europäisch entwickelten und produzierten Produktes für die indische Rolling Stock Industrie. Die dabei berücksichtigen Themenschwerpunkte, die im Detail betrachtet sind über:

Welche Standards werden derzeit in Indien bzw. in Europa offiziell für den Zulassungsprozess herangezogen? Aktuelle Situation erfassen.

Vergleich der technischen Zulassung Standards zwischen IR (Indischen Railway) Standards und "EN Normen". Unterschiede im Detail zusammenfassen.

Woher kommen die Unterschiede: des Stand der Technik (Normen/Gesetze/Regelwerk)

Empfehlung für eine erfolgreiche Zusammenarbeit /Vertragserfüllung:

1. Vertragliche Berücksichtigungen/Integration in Ausschreibungen.

2. Basis eines Vorschlags von Verantwortlichkeiten Lieferant/Kunde/Behörde anhand einer Matrix.

3. Ausblich zu eine Anpassungen des IR Standards an UIC.

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List of abbreviations

TEU	Twenty foot equivalent unit
UIC	Union International des chemins – International union of Railways
IR	Indian Railways
RDSO	Research design and standards organization
IC	Intercity
ICE	Intercity express
R&D	Research and development
EU	European Union
CIS	Commonwealth of independent states
CNR	China north locomotives & rolling stock industry
CSR	China south locomotives & rolling stock industry
UNIFE	Union des industries ferroviaires Européennes (The European rail industry)
CER	Community of European railways
DB	Deutsche Bahn
EN	European norms
TSI	Technical specifications for interoperability
ED	Executive director
DG	Director General
OC	Oscillograph car
OT	Oscillation trials
1 Lakh	0.1 Millions
1 Crore	10 Millions
Kmph	Kilometers per hour

1 Introduction

This master thesis is the evaluation & analysis of the homologation process for rolling stock approval in Europe and in India. The main aim is to find out; the key factors for successful homologation of European designed and developed rolling stock products, for Indian Railways, which will be operated on the track of Indian railways.

This document majorly covers about the Engineering tests and trials those makes an important contribution to ensuring the safe, reliable and economical use of the technical systems deployed in today's railway systems. The high complexity of modern railways demands the system wise examination of the interplay of individual components within the entire integrated railway system.

The establishment of this document is based on existing rules, practices and procedures. The following principles are applied:

- The railway system requires comprehensive technical rules in order to ensure an acceptable interaction of vehicle and track.
- Due to the numerous national and international regulations new railway vehicles had to be tested and homologated before putting them into service. In addition, existing acceptance had to be checked when operating conditions were extended.
- In view of the increasing significance of international traffic, in particular of high speed traffic, the standardization of existing regulations is required. In some cases, additional rules are required as well. An update of existing regulations is also needed due to the considerable progress achieved in the field of railway-specific methods for measuring, evaluation and data processing.
- It is of particular importance that the existing level of safety and reliability is not compromised even when changes in design and operating practices are demanded, e.g. by the introduction of higher speeds, higher wheel forces, etc.

This document also takes account of the present state of the art, which is generally applicable for test procedures and the evaluation of stationary and 'on-track' tests in Europe and in India. The main intention of this thesis work is to find out the followings factors for the smooth homologation of rolling stock, designed and developed in Europe for Indian Railways.

- Various standards used for homologation in Europe and in India
- Rolling stock in India
- Tracks in India
- Final Rolling stock approval authority in Indian railways (i.e.RDSO).
- Procedure followed by Indian Railways for approval of rolling stock.
- Comparison of the approval procedure with UIC & Indian Railways.
- Possible suggestions for changes/adjustment in the Indian railways procedures.
- Responsibility matrix when working with Indian Railways.
- Recommendation for systematic working with Indian railways.

In summary of this thesis, there is systematic approach for homologation of rolling stock in India with excellent working collaboration with approving authority of IR.

2 Worldwide rail market

In most parts of the world, almost all segments of the rail sector are on a course of growth. This applies for freight as well as passenger transport, both within cities and metropolitan regions as well as on long-distance lines. The increasing transport demand can only be covered by acquiring new vehicles. In particular, the developed markets in Western Europe and North America also provide high potential for replacement procurements. The procurement boom has continued for some years now. However, not all manufacturers have benefited equally from the increasing demand for rolling stock. Individual manufacturers have developed their own strategic individual positions in light of the industrial structures, competitive constraints and growth strategies of the single markets[1].

2.1 Mobility trends

2.1.1 Infrastructure

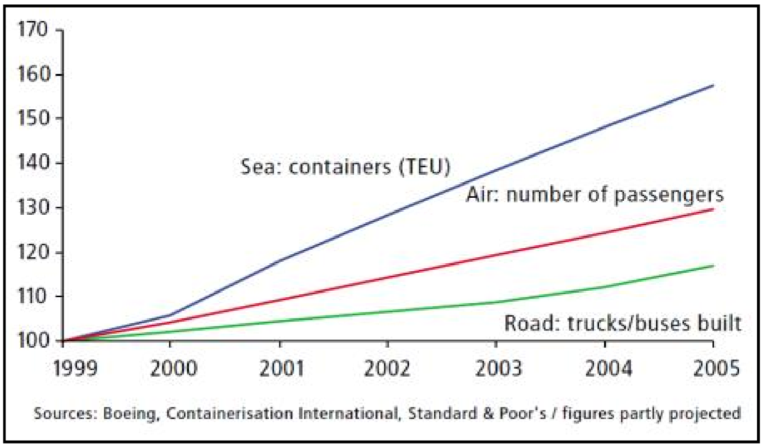

Figure 1 Worldwide transport indicators[2]

The key issue with the regard to the future is how demand for transportation can be met in the years ahead. The scale of growth suggests that the combined capacities of all existing modes of transport will be required in order to create a sufficient range of transport services for the future. The often still lauded competition among modes of transport is in many respects (urban traffic, for instance) a thing of the past.

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[1] http://www.sci.de/uploads/tx_edocuments/Marketingkit.pdf page 2 of this document.

[2] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 9 of this document.

For this reason, all the forecasts for individual transport systems are fundamentally based on strong growth. This applies to road-based transport as well as to air transportation or sea shipping. Coping with this growth is the key task for the future facing every mode of transport.
A significant constraint on the expansion of transport services for all modes of transportation is the infrastructure. This applies equally to roads, airports, ports, or railway lines. The construction and expansion of these installations is not only extremely cost intensive but also particularly in the especially congested conurbations often barely feasible or completely impossible owing to lack of space alone.
In Western countries in particular, due to space problems, the construction and expansion of the infrastructure is linked to planning and approval procedures which take up a lot of time or even make the relevant projects impossible, for environmental protection reasons, for example.
New infrastructure is viable especially in those regions with adequate space reserves and where approval proceedings are swift as in Central & Eastern Europe. In the conurbations, at least, any expansion of infrastructure to match the expected growth in transport demand is frequently barely possible. The future range of transport services will therefore focus on the modernization and hence best possible exploitation of existing infrastructures. Reserve capacity in the networks needs to be developed. All modes of transport must increase their specific efficiency especially at the nodal points and interfaces as well as improving their intermodal interaction. The future focus will be less on competition and more on efforts to combine means of transport intelligently[3].

2.1.2 Renaissance in rail transport

The growth in transport demand together with the infrastructure constraints have again put the railway industry increasingly at the focus of transport planners' attention over the past ten years. After all, especially with regard to their infrastructure, rail bound systems hold two crucial advantages:
– Rail networks already exist in most regions and countries, but especially in metropolitan areas; there is an accessible railway station to be found near the center of every medium-sized town, not only in Western Europe.
– The current utilization of the networks is compared with the rate of utilization of roads and airports in many conurbations relatively low. Most of the bottlenecks occur at the junctions. But here expansion is possible with at least moderate space consumption without requiring any vast extension of the rail infrastructure. Hence, the railways have an abundance of spare capacity.

Moreover, the technical advantages offered by the rail system, such as its mass transportation capacity and potential for integration as well as traffic plan ability, are making rail bound transport attractive to many countries again.
Rail transport's greatest growth potential lies chiefly in inner-city transport operations (e.g., metro and light rail services), commuter transport, and services between towns and the surrounding region (e.g., local and regional rail links), and the point-to-point connections between individual metropolitan areas (e.g., IC/ICE services), as well as in high-capacity freight transportation.

[3] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 9, page 10 of this document.

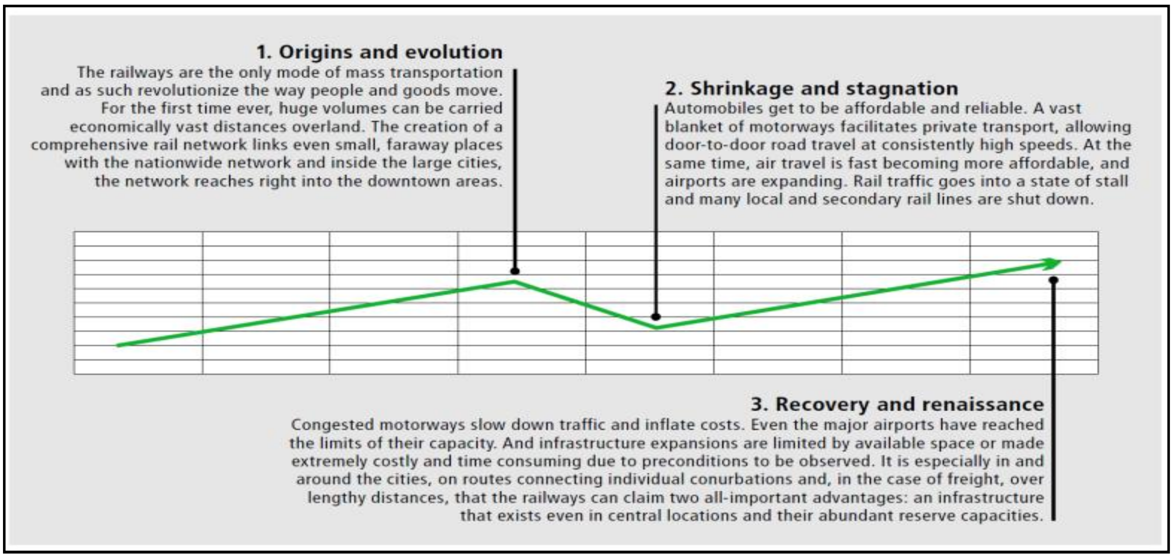

Figure 2 Phases in rail history[4]

As a consequence of this trend, passenger transport by the standard-gauge railways increased between 1997 and 1999 by 5 percent worldwide and in freight transportation by 6 percent, following a clear decline up to the mid-1990s as a result of the severe recession in Eastern Europe and in the Commonwealth of Independent States (CIS). The number of urban rail transport systems has also risen by 6–7 percent since the mid-1990s[5].

2.1.3 Deregulation driving the market worldwide

The former state railways were responsible not only for transporting passengers and goods but also for the vast majority of the services required for that purpose. This included the construction and maintenance of vehicles as well as the building of the infrastructure and even the management of station buildings. In some countries, such as India, this is still the case today. Virtually the whole railway industry in that country therefore belongs to the state-owned railways.

Owing to the developments described at the outset, a reform of the railways has been taking place in many countries since the late 1980s. The first great railway nation to modernize its rail industry was Japan. This reform included the break-up into various operating companies. Reform has taken place in virtually all parts of the world since then. In South America, for instance, it resulted not least because of the public sector's financial constraints in a privatization wave, especially in freight haulage. In Western Europe, EU legislation has proved to be the engine of reform.

A chief consequence of virtually all reforms was the railways' concentration on their „core business," the actual running of their services. Depending on the prevailing ideology and the requirements in the individual countries, support functions such as the planning, construction and maintenance of the infrastructure and vehicles were or are being outsourced or privatized. In some cases, the redefinition of interaction between the individual protagonists has given rise to completely new functions, such as the leasing of rail vehicles, which was previously largely unknown in Western Europe

[4] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 11 of this document.

[5] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 11, page 12 of this document.

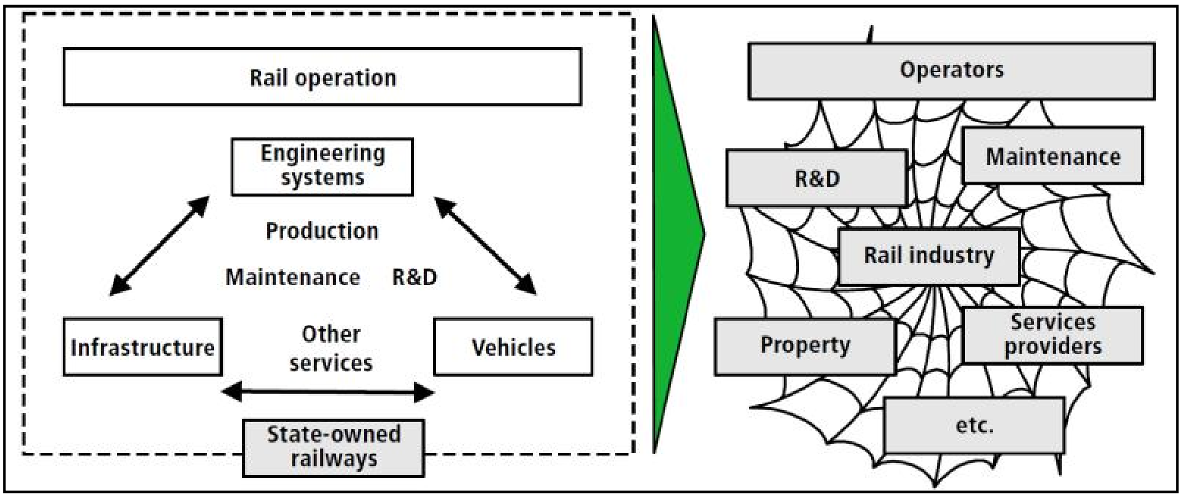

Figure 3 Outsourcing in response to deregulation[6]

This deregulation drive is set to continue in the future, not least owing to the inherent pressures such as the increasing lack of public sector funding or the growing need for cross-border traffic. This is also borne out, for example, by the EU's current planned legislation for local public transport, which will bring deregulation for urban transport services following on from the standard-gauge railway. Numerous privatizations, which have yet to be fully completed, have also been carried out in the accession states of Central and Eastern Europe in recent years.

For the companies of the rail industry the growth of their market through these reforms is currently still much more important than the overall growth in the rail segment driven by rising transport demand[7].

2.1.4 The rail market's structure

As a result of the tendency of most national railway networks to cut themselves off from their counterparts, greatly differing structures in terms of operation and technology exist worldwide. Whereas in a comparatively large country like Germany, there is still a distinction between long distance and short-distance passenger transport, which is even reflected institutionally in the structure of the former state railway, in its smaller neighboring countries this is often much less significant or completely irrelevant. While the differing technological requirements between urban rail transport and the so-called "standard-gauge railway" are even enshrined in law in Germany, such a distinction in some of the urban transport systems in South America, for example, would be hard to follow.

In order to subdivide rail transport with regard to the development of the market for rail engineering products, it is necessary to draw a fundamental distinction with the modes of traffic in the standard gauge railway between passenger and freight transportation. In passenger transportation, a further distinction can be drawn between local and long

6 http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 13 of this document.

7 http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 13, page 14 of this document.

distance traffic, with the high speed segment within long distance traffic being treated separately.

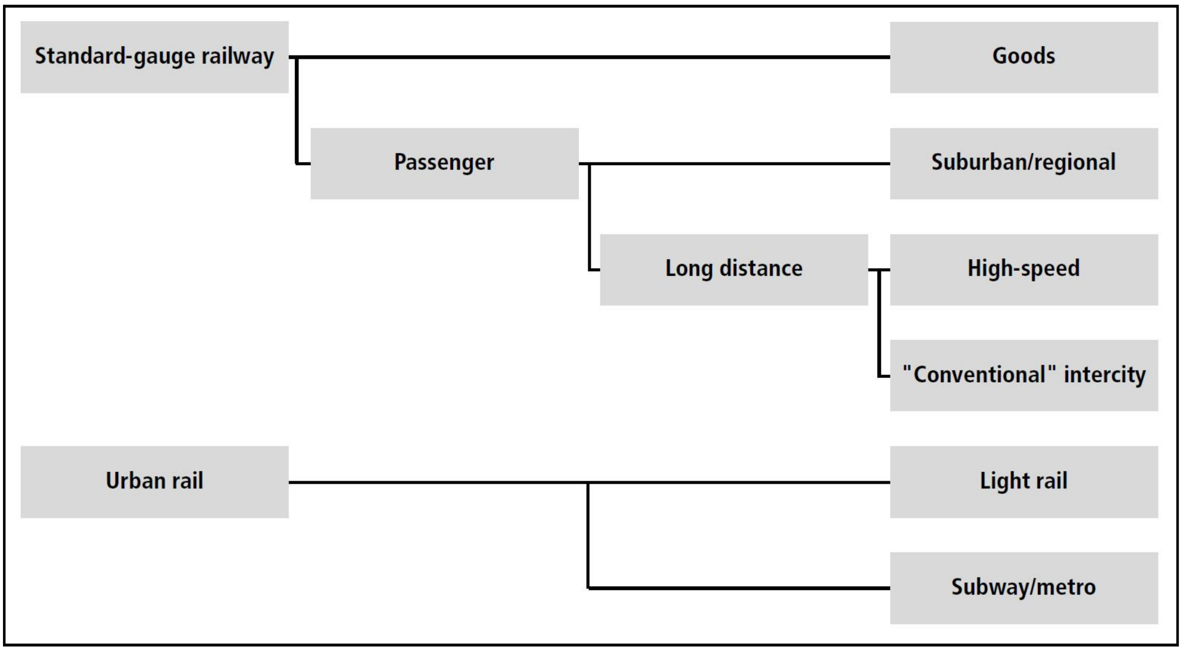

Figure 4 Rail markets [8]

All modes of traffic possess their own structure with their own requirements in terms of the relevant equipment and correspondingly with a differing market development and relevance.
If investment costs of, for example, €3 million per kilometer are sufficient for the construction of a new single-track, non-electrified railway line for freight haulage in Germany, the spending on a new ICE high-speed line can easily amount to €20 million per kilometer and more. The market survey must also draw such distinctions. At the system level in the vehicle segment alone, there are a large number of varying products with individual properties which are used in the differing modes of traffic[9].

Vehicles and modes of transportation

Based on the various modes of traffic, their requirements and product configurations, SCI Verkehr has developed a product matrix from which a worldwide analysis of the rail market is possible within the meaning of a benchmark. The product matrix has three layers of analysis:
– The breakdown of the rail market into various product groups,
– The study of these product groups with regard to the physical inventories, the annual market volume and the development of this volume
– And the examination of the varying geographical markets worldwide[10].

[8] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 15 of this document.

[9] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 15, page 16 of this document.

[10] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 16 of this document.

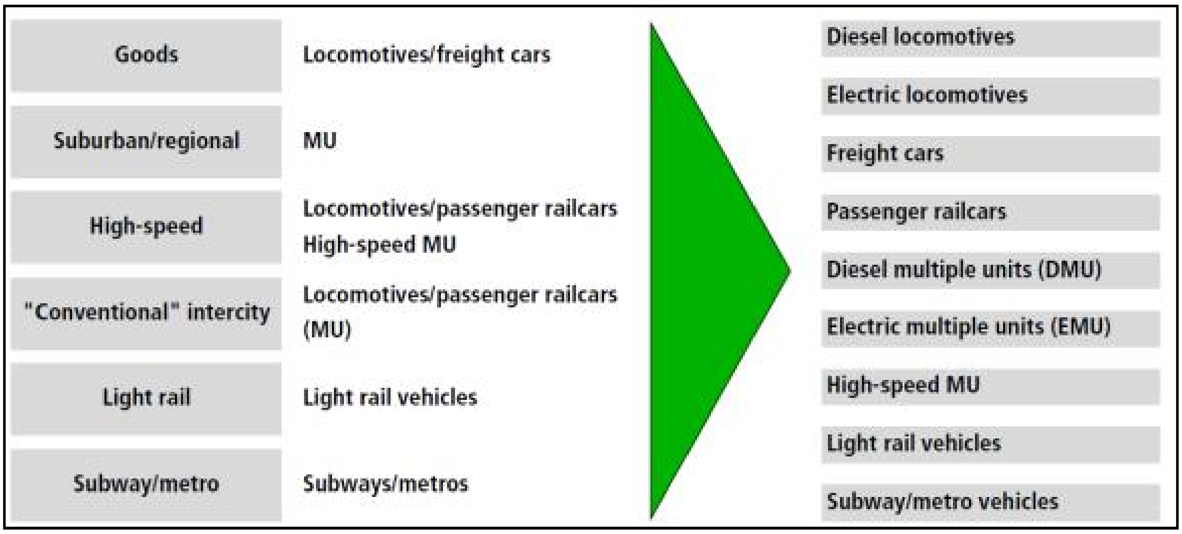

Figure 5 Vehicles and modes of transportation[11]

Transport by regions

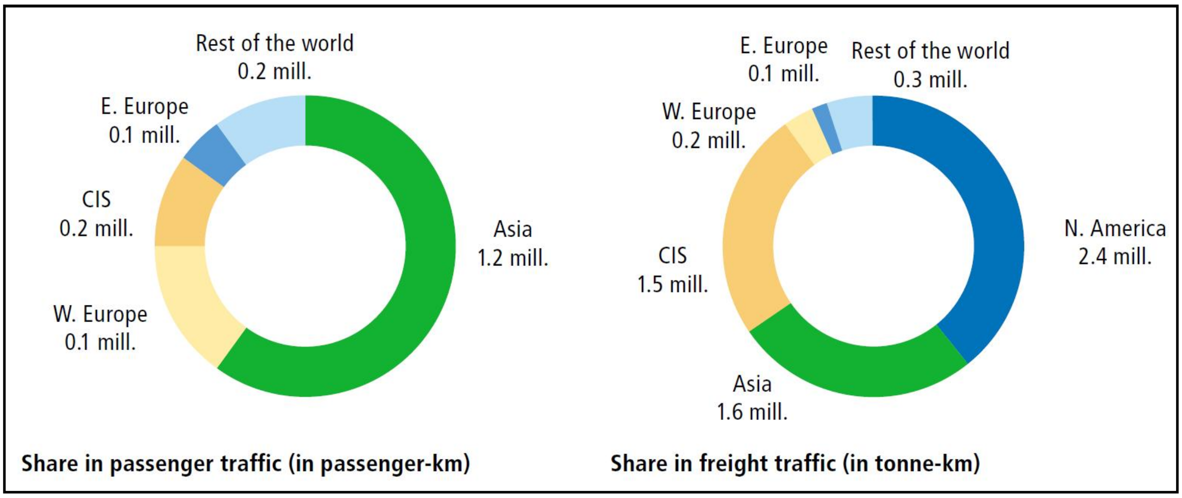

Figure 6 Transport by regions[12]

[11] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 16 of this document.

[12] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 19 of this document.

2.1.5 Rail engineering product matrix

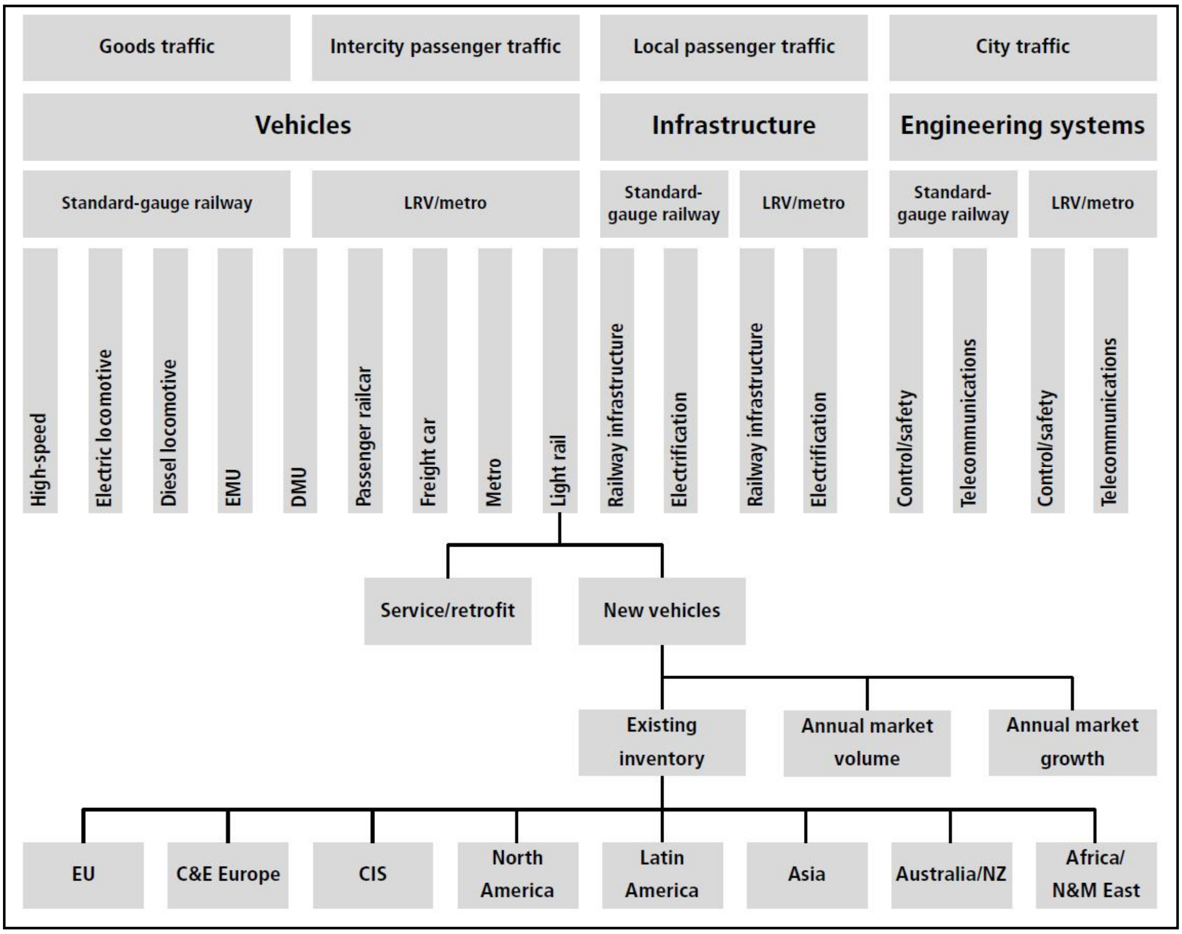

Figure 7 Rail engineering product mix[13]

The rolling stock, meaning the vehicles themselves, the track infrastructure including its electrical equipment and engineering systems can be identified as the basic product groups in railway engineering[14].

[13] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 17 of this document.

[14] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 18 of this document.

2.2 The worldwide rail market

Based on the analysis of markets in individual countries, SCI Verkehr estimates the worldwide rail market at currently about €56.7 billion per annum. The annual growth over the next five years for all regions and submarkets is assessed at about 4 percent.
Even though the infrastructure and vehicles form the biggest individual markets, the fastest growing sub segment is engineering systems. This also illustrates the great challenges facing the intelligent organization of rail traffic in the future.

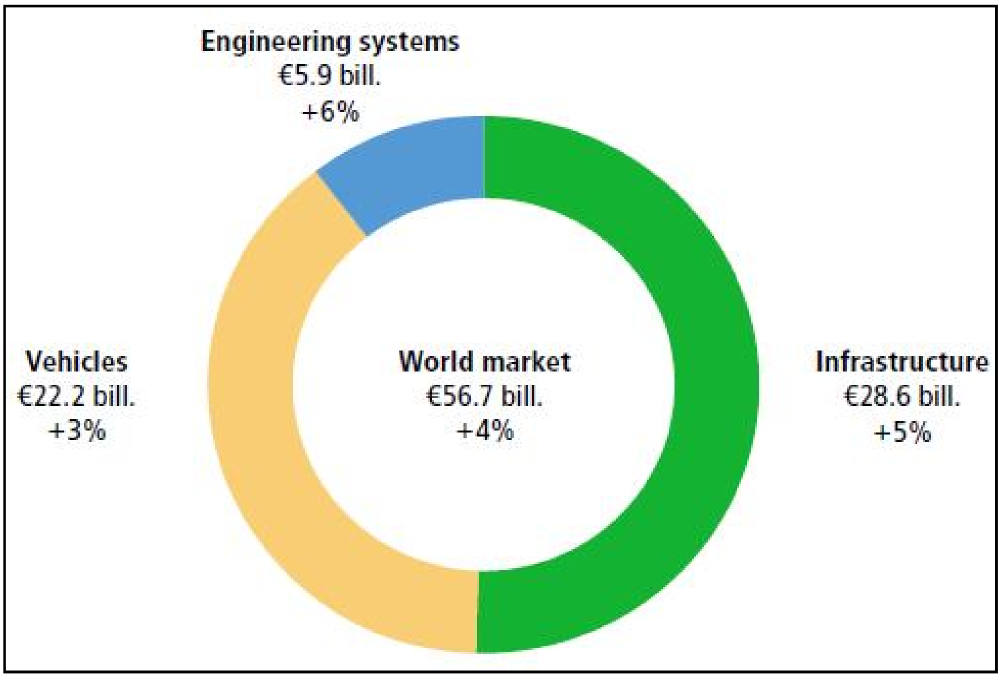

Figure 8 The world market for railway engineering by segment[15]

Western Europe will remain the most significant market for rail industry products. The growth in transport demand described will continue to ensure substantial growth in market volume. In absolute terms, this growth is the biggest worldwide but owing to the region's high stock levels is moderate in percentage terms.
Asia is also of outstanding importance with its enormously extensive rail networks. However, demand for solutions from Western manufacturers exists only in subsectors within this region. In many markets mass transportation exists in the form of very simple solutions which can be provided by domestic manufacturers at low cost, such as in freight transportation in China or India. The greater part of the markets in individual countries is largely closed to Western suppliers. Exceptions exist in areas where high-quality solutions are needed which cannot, however, be provided by domestic suppliers.

This is especially the case with engineering systems as well as in some specific segments, such as high-speed transport or in some instances in the metro sector. Substantial growth is to be expected in this area due to the rapid pace of development.
North America is of interest to European manufacturers chiefly in those segments where there is pent-up demand compared with Europe, as is the case in passenger transport. Significant market opportunities exist for foreign companies in suburban standard-gauge railway transport, in the light rail rapid transit segment and in high-speed transport. The

[15] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 54 of this document.

dominant freight transport segment, on the other hand, with its specific North American volume-dominated character is already well covered by domestic manufacturers.

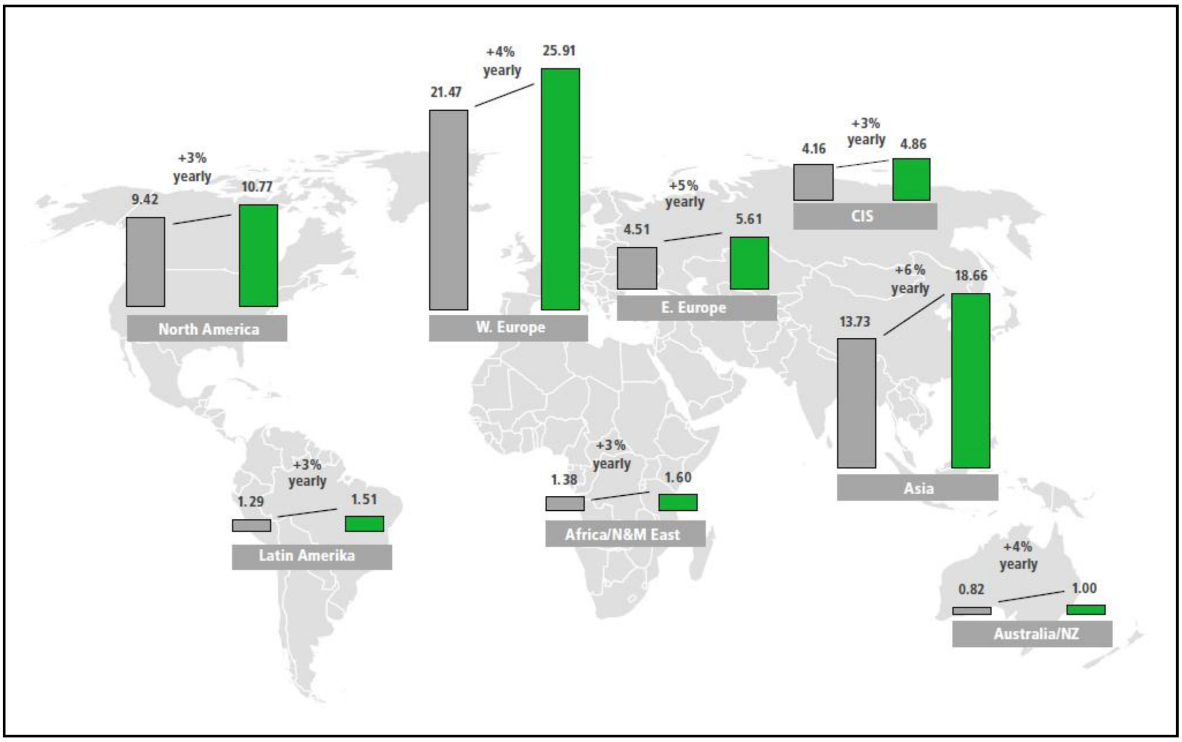

Figure 9 The world market for railway engineering by regions[16]

Eastern Europe and the CIS offer the most interesting prospects worldwide. After railway transport suffered a drastic slump in the early to mid-1990s, the first signs of recovery are already starting to emerge above all in the accession states. In Hungary, for instance, both freight and passenger transport services have been rising again since 1996, whereas other countries, especially in the CIS, will need a few more years for this process. Due to scarce financial resources, very few or no procurements were made in these countries in the 1990s, in which the railway still represents the backbone of distribution in many transport areas. As a result of this situation, both the infrastructure and rolling stock are in a state which makes investment urgently necessary despite the shortage of available funds. In the EU accession countries, investment has increased over the past 2-3 years chiefly in the form of EU subsidies. The first large-scale invitations to bid for the upgrading of main lines are currently being put out, with a clear increase in vehicle orders also being registered. As the locomotive and power car procurements in Hungary and Romania show, high quality products from Western suppliers are being opted for increasingly. This is not least linked to the fact that some of the funds for capital investments come from the EU. For this reason, the forecast for the Eastern European market in the next five years is comparatively optimistic. For the CIS, such growth in market volume will presumably occur in the years that follow.

Australia and South America remains comparatively small markets with promising growth in individual segments. In South America, the main such segment is freight transportation which owing to the privatizations of recent years in such countries as Argentina and Brazil has gained new scope for investment. In Australia, the harmonization of regionally differing network structures is leading to growth chiefly in the infrastructure[17].

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[16] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 55 of this document.

[17] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 56 of this document.

2.3 Market summary

The rail market will remain an exceedingly attractive future market for those companies which possess specialized experience and proven expertise as well as the required certifications in this segment and are able to adapt to the increasing internationalization of markets. This favorable assessment is based on the following findings:

– Thanks to the rising demand for mobility, worldwide rail traffic is also growing, as is the demand for railway technology products and services;

– Through the opening-up of world markets new transport routes are being created and existing routes largely renewed and modernized as part of extensive national and supranational investment programs. This will create continuous significant growth for the foreseeable future, including for the rail sector;

– Thanks to the deregulation of rail traffic, the market volume for private sector companies is rising even more strongly not least because of reform and procurement bottlenecks, similar to the situation that existed in telecommunications or the energy supply industry in recent years.

– Railway technology is a specialized market with specific requirements, which result chiefly from high safety standards linked to the transportation of passengers and goods. Technical expertises together with the required certifications are the basic capital of the companies operating in the rail industry. In a relatively restricted (world) market with a limited total volume, this creates very high entry barriers which deter newcomers or those coming in through the back door from other industrial sectors while benefiting established specialists.

In the world market for rail equipment, average growth rates of about 4 percent will continue to be realized, although this is only a mean value. Especially in Western Europe, the largest and most attractive market for railway technology products, there are signs in some countries of a stretching and reduction of public investment budgets due to continued economic problems. Nevertheless, major transport schemes always represent national prestige projects as well, which as in the case of high-speed lines, for example, are treated as a priority. In contrast, in the same countries against a background of increasing competition for the operation of lines and networks in both municipal and rail transport the successful players are investing heavily in measures aimed at boosting the appeal and efficiency of the railway system. In the EU accession states, large scale financed investment is about to be effected in the infrastructure especially. In Asia, capital spending is focusing on efforts to cope with local urban transport as well as commuter traffic between towns and the surrounding areas, with some high-speed rail links also being funded.

In summary, it can be concluded that the developments in the individual countries and regions will very much vary in pace depending on national policy, procurement programs and prioritization. For the rail industry's manufacturers, perceiving these trends in good time, assessing them correctly and taking them into due account are crucially important to their success or failure.

Through a consistent analysis of market trends with a substantiated assessment of the underlying national conditions and priorities as well as an evaluation of the respective financing solutions, it is possible to create a valid early warning system for operating in these markets very successfully. Vossloh has broken new ground with this consistent approach, which other companies in the sector must also follow in future so that they too can hold their own in the long term in a world rail market that is becoming increasingly complex[18].

[18] http://www.lerail.com/IMG/pdf_rapport-sci-worldwide.pdf page 57, page 58 of this document.

3 Rolling Stock

Definition

Rolling stock comprises all the vehicles that move on a railway. It usually includes both powered and unpowered vehicles, for example locomotives, railroad cars, coaches, and wagons. However, in some countries (including the United Kingdom), the term is usually used to refer only to unpowered vehicles, specifically excluding locomotives, which may be referred to as running stock, traction or motive power[19].

Solutions for moving people and goods- Rolling stock

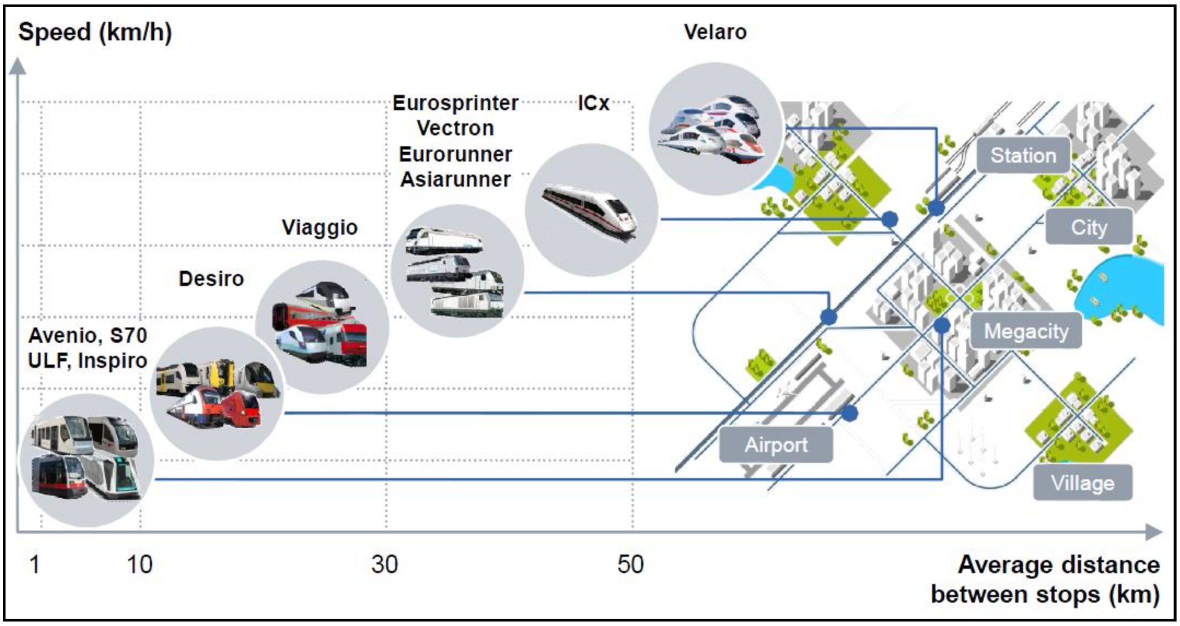

Figure 10 Solutions for moving people and goods[20]

[19] http://en.wikipedia.org/wiki/Rolling_stock

[20] Siemens corporate presentation English, slide number 8

3.1 Overview worldwide

Asia is not most important market region – Americas and Africa/middle east with high growth expectations.

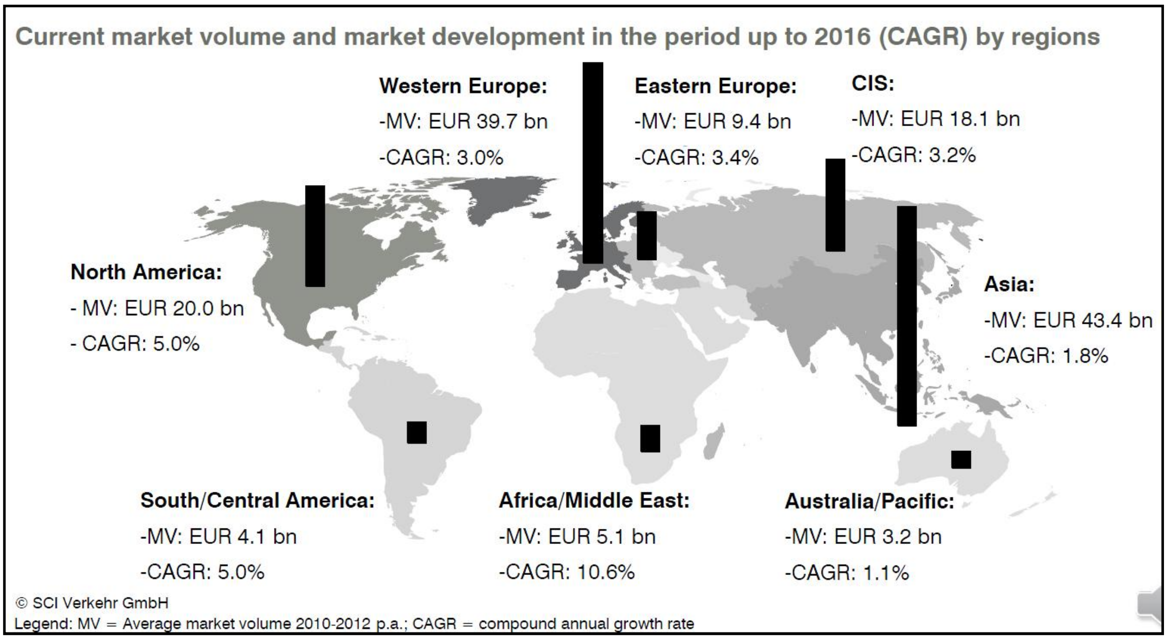

Figure 11 current market volume and market development by regions[21]

Countries ranking: china remains no.1 – Russia with strong growth close to USA.

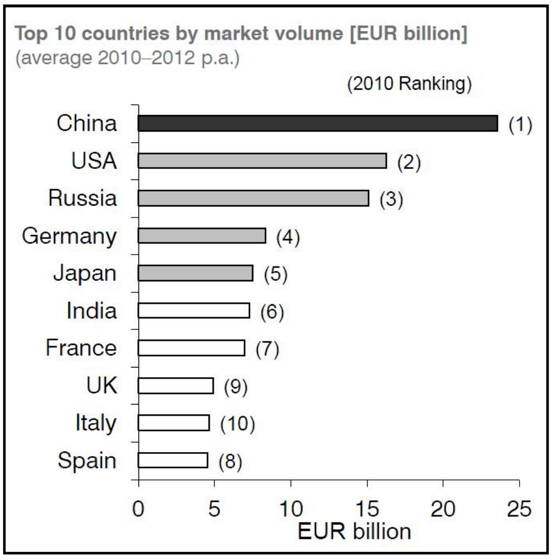

Figure 12 Top 10 countries by market volume [22]

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[21] http://www.sci.de/fileadmin/user_upload/WM2010_2012/120906_MARKET_FOR_RAILWAY_TECHNOLOGY_2012.pdf page 13 of this document.

[22] page 14 of this document.

Chinese rail market hit its peak but will remain number one

- Effects of stimulus programmes finished – growth from after-sales
- High long term market volumes due to investments in urban rail transport and rail freight transport

Russian (and CIS) rail market made up ground

- Increasing quality level of railway products
- Shortage of freight rolling stock

Europe's market weakened due to budget and euro crisis – investments mainly depending on public spending[23].

Infrastructure market with highest growth rate for the next 5 years

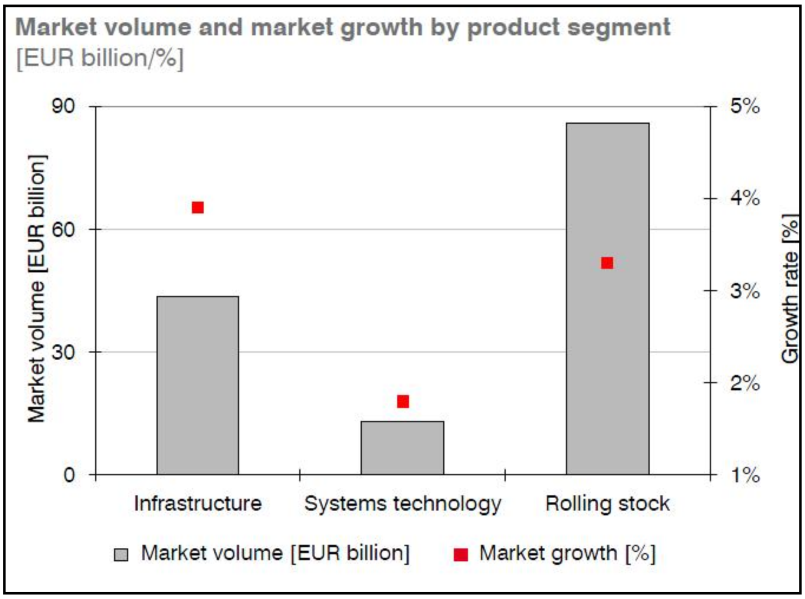


Figure 13 Market volume and market growth by product segment [24]

- Infrastructure: Highest growth rate driven by dedicated freight lines
- System technology: Small growth on high level with long-term growth options to increase capacities
- Rolling stock: Growth along the total market growth mainly driven by after sales and higher product prices [25]

23 http://www.sci.de/fileadmin/user_upload/WM2010_2012/120906_MARKET_FOR_RAILWAY_TECHNOLOGY_2012.pdf page 14 of this document.

24 page 15 of this document.

25 page 15 of this document.

Urban rail market is the driver of growth for the global rail market.

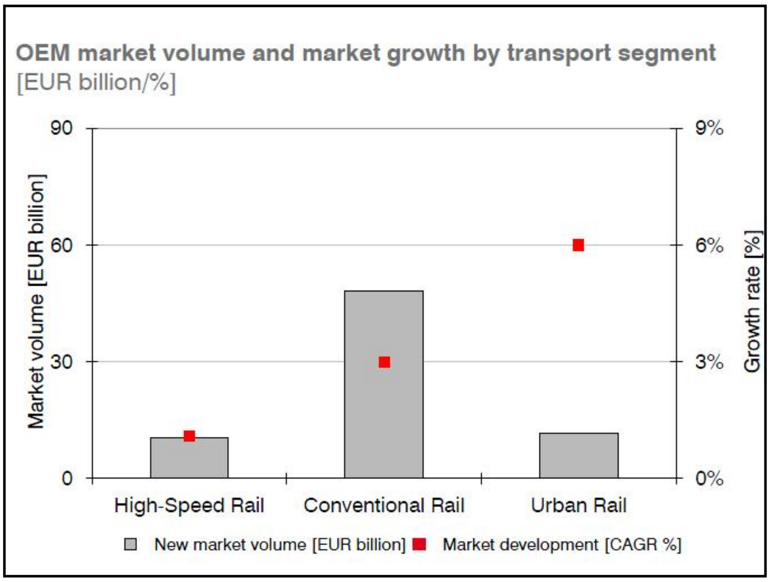
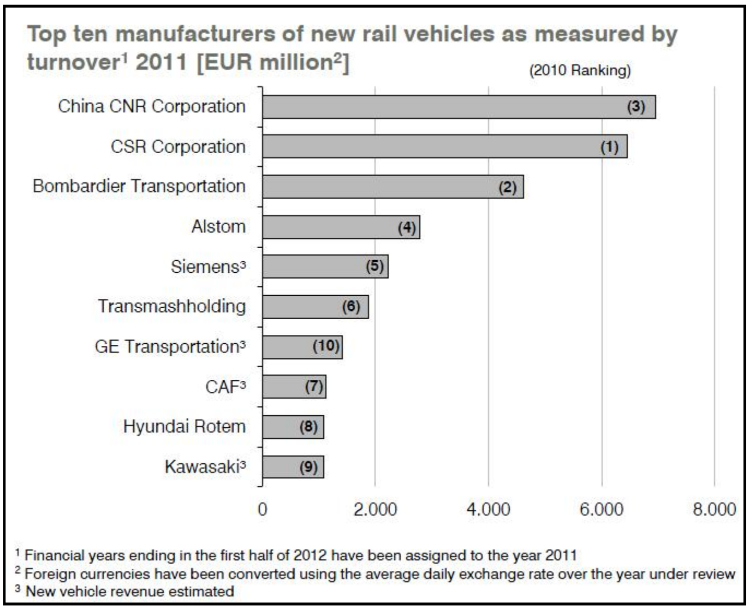


Figure 14 OEM market volume and market growth by transport segment[26]

Urban rail - has been the driver of growth for global rail market. A bad traffic situation in cities leads to long-term, stable growth. High-speed rail - Peak reached projects in emerging countries with long delays because of high investment volumes. Conventional rail Investments mainly driven by new freight lines.

Top ten rolling stock manufacturers – Chinese manufacturers hit records levels future over capacities will strengthen competition.



26 http://www.sci.de/fileadmin/user_upload/WM2010_2012/120906_MARKET_FOR_RAILWAY_TECHNOLOGY_2012.pdf page 18 of this document.

Figure 15 Top ten manufacturers of new rail vehicles[27]

CNR and CSR increased revenues significantly – top players for new rolling stock deliveries. Chinese players intensify their export activities significantly – future overcapacities expected because of shrinking Chinese OEM market. Also in other established markets, demand for railway technology products under pressure. That results in strong competition on export as well as established railway markets.

After sales market with higher growth rate – opening still strategic challenge for railway industry.

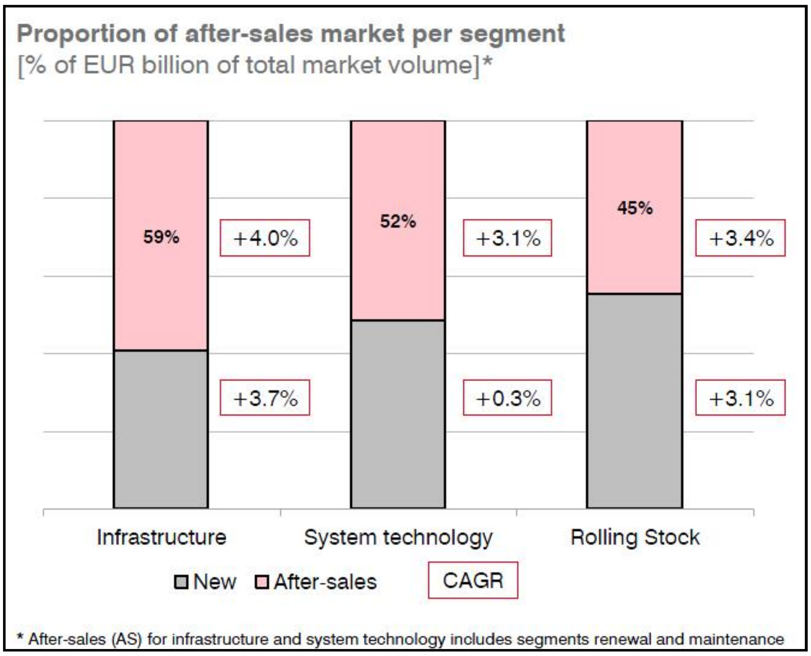


Figure 16 Proportion of after sales market per segment[28]

After Sales (AS) market with higher growth expectations compared to new markets.
But main volumes in established markets still in the hand of operators.
Strategic challenge: To enter the AS market outside contracts for new equipment (e.g. long-term maintenance contracts for rolling stock after delivery). To adapt business structures to the needs of AS market.

3.2 Rolling stock Manufacturing

A locomotive, DMU, EMU, or rail car is built from a series of progressively more complex assemblies and subsystems that may be manufactured in-house or purchased from other railway rolling stock companies (figure 17). Wheels are attached to axles, which in turn are

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27 http://www.sci.de/fileadmin/user_upload/WM2010_2012/120906_MARKET_FOR_RAILWAY_TECHNOLOGY_2012.pdf page 19 of this document.

28 page. 20 of this document.

attached to an assembly built to house the axles, brakes, a traction motor, transmission, and a spring suspension for the locomotive known as a “truck.” Rail cars are built similarly but do not have traction motors or a transmission incorporated. At least two complete truck assemblies are then attached to a frame, which will support the machinery of a locomotive or the body of a rail car. In the case of a diesel-electric locomotive, the frame will support a diesel engine, electric generator, air compressor, high-voltage control assembly, and a crew cab complete with electronic engine controls, and brake controls, and communications equipment. The production process for locomotives is labor-intensive, demanding skilled and experienced workers to assemble and integrate the numerous subsystems. Labor input on rail cars is not as high as on a locomotive, typically about 10 percent of overall cost. A DMU has a diesel engine for motive power; an EMU has an electric motor for the same. Both have a conductor’s cab, and passenger seats installed in each car. The frame of a rail car will support a body constructed from welded and riveted steel beams, structural shapes, and plates, to meet customer’s demands.

The railway rolling stock industry is the largest single consumer of steel castings in the United States, accounting for half of all such shipments in 2009, by volume. Although locomotive and rail car manufacturers produce some of their own parts, parts producers in the United States typically are not integrated with equipment manufacturers. Suppliers of major systems, such as air brakes and engine controllers, work with locomotive and rail car manufacturers to assure safe and efficient integration of their products during assembly.

Manufacturers of these castings develop and document their processes and inputs, and allow their customers to audit this information. Other significant inputs are diesel engines, electric traction motors, and the electronics necessary for engine control and communications equipment[29].

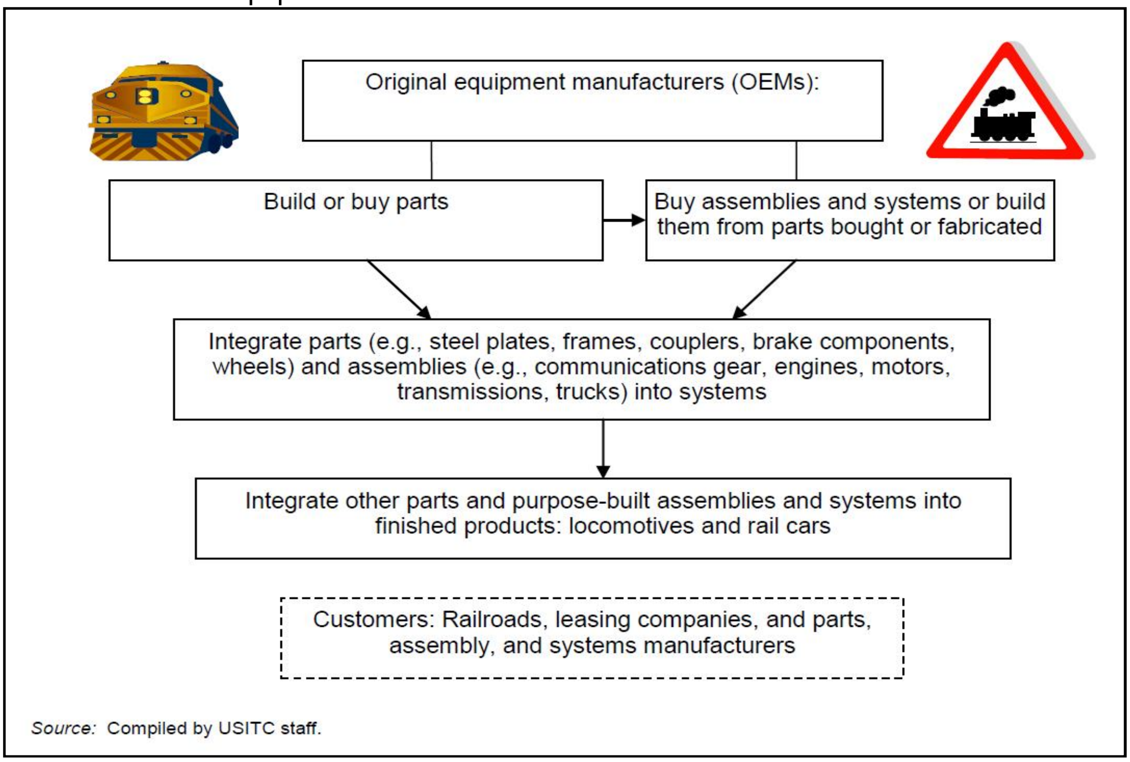

Figure 17 Railway rolling stock production process[30]

[29] United states international trade commission report on rolling stock- March 2011, Page 19 of this document.

3.3 Rolling stock Manufacturers

Around 170 companies manufacture rolling stock at approximately 330 sites worldwide. Between 2006 and 2010, the Chinese manufacturers CSR and CNR nearly tripled their turnover and CSR Corporation was the first Asian manufacturer to occupy top position in the manufacturer rankings in 2010. China CNR Corporation is roughly equal with second placed Bombardier Transportation in third place. In general, particularly passenger coach manufacturers have developed positively over the last few years. There are no longer any pure freight wagon manufacturers among the ten most successful manufacturers.

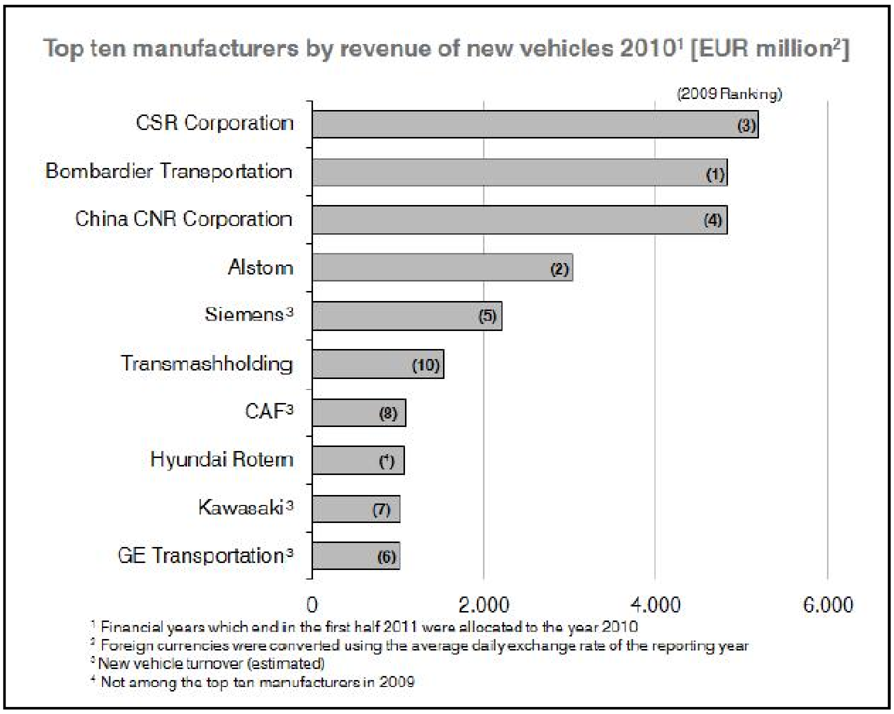

Figure 18 The top ten rolling stock manufacturers worldwide [31]

The shift in the balance of power is not due to a structural weakness of the established manufacturers Bombardier, Alstom and Siemens, but results instead largely from the fact that CNR and CSR operate in a politically controlled domestic market with very large scale high-speed and metro projects. CNR and CSR still have to prove whether or not they can compensate for the expiring contracts in China by gaining foreign contracts and therefore be able to continue their growth in the future too. The Chinese manufacturer currently generates less than 10% of their turnover by exports albeit on an increasing scale. Occasionally fatal accidents (both on completely new metro systems and state-of-the-art high-speed lines) mean that Chinese railway technology products first have to regain the confidence of the foreign markets. The highly regulated European markets will provide established manufacturers with a safe area in the medium term too. The most dynamic accessible markets can currently be found in South America. Many European and North American manufacturers have therefore opened production sites in this region in the last few years[32].

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[30] United states international trade commission report on rolling stock- March 2011, Page 20

[31] http://www.sci.de/uploads/tx_edocuments/Marketingkit.pdf page 6 of this document

[32] http://www.sci.de/uploads/tx_edocuments/Marketingkit.pdf page 6 of this document

3.3.1 The 60 Most Important Rolling Stock Manufacturers

Analysis of production sites

The 60 largest manufacturers and their approximately 200 production sites currently share more than 90% of the rolling stock market between themselves. In total, the global sector for rolling stock production consists of around 170 companies with 330 sites. The distribution of production sites is largely oriented towards the distribution of demand worldwide. The Eurasian double continent, consisting of Europe, the CIS and Asia, features the most important market for railway technology worldwide. Therefore, 80% of all currently active vehicle manufacturers and 75% of worldwide production sites can be found in these regions.

Approximately 40 manufacturers come from the Eastern European region, the smallest of the four railway markets. The reason for this is that most countries established their own rail vehicle industry after the collapse of the Soviet Union, which has not yet been consolidated. Correspondingly, each company headquartered in the region has only 1.3 sites. The situation in the CIS is similar: Whilst vehicles for passenger transport and locomotives have widely been consolidated to Trans mash holding and most, by far to Sinara, the freight wagon market is very fragmented and their high sales levels do not make consolidation necessary in the short term. Manufacturers in the CIS have an average of under 1.5 sites. Asia has the most production sites for rail vehicles with nearly 80 sites, closely followed by Western Europe. Besides other important manufacturers, four of the ten largest manufacturers are located in Asia and Western Europe. Since the manufacturers account for a number of production sites, in Western Europe each manufacturer has 2.1 sites and in Asia 2.2 on average[33].

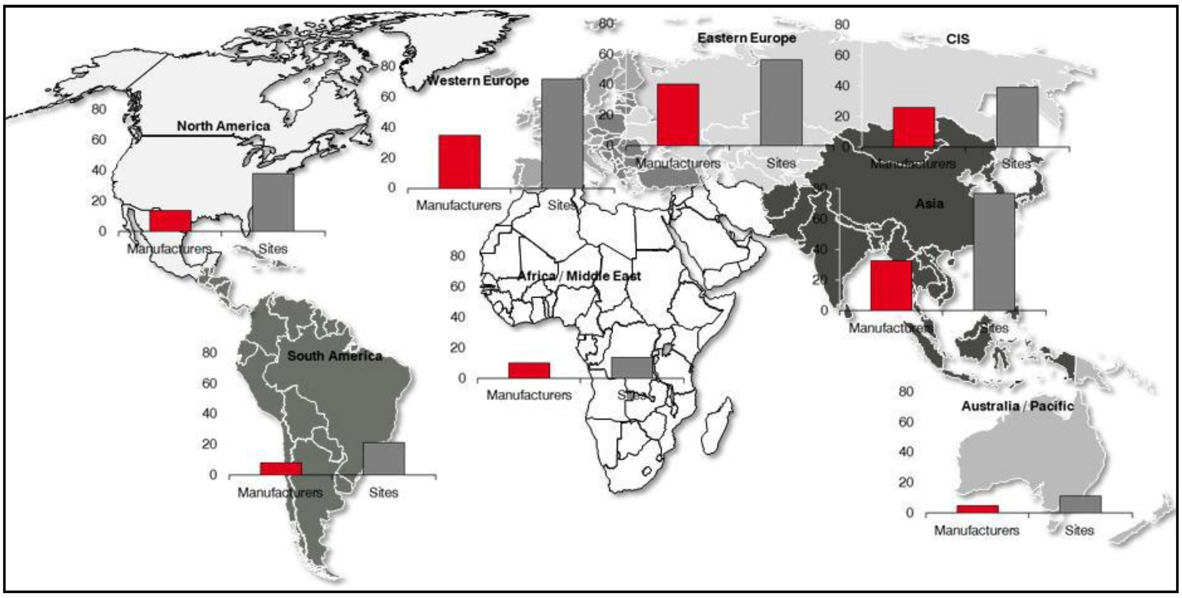

Figure 19 Worldwide distribution of manufacturers and sites[34]

[33] http://www.sci.de/uploads/tx_edocuments/Marketingkit.pdf page 7 of this document

[34] http://www.sci.de/uploads/tx_edocuments/Marketingkit.pdf page 7 of this document

List of the 60 most important rolling stock manufacturers worldwide

1	Alstom Transport	33	Niigata Transys Co Ltd
2	JSC Altaivagon	34	Nippon Sharyo
3	American Railcar Industries	35	Patentes Talgo S.L.
4	Amsted Maxion S. A.	36	Pesa Bydgoszcz SA Holding
5	AnsaldoBreda	37	Rail Coach Factory (RCF)
6	Astra Vagoane Calatori	38	OJSC Ruzkhimmash – Russian Corporation of Transport Machinery (JSC RCTM) Plant
7	OJSC Azovmash	39	Siemens Rail Systems
8	Bharat Earth Movers Ltd (BEML)	40	OJSC Sinara Transport Machines (STM)
9	Bombardier Transportation	41	Skoda Transportation
10	China CNR Corporation Limited	42	Stadler Rail Group
11	Chittaranjan Locomotive Works (CLW)	43	Tatravagonka a. s. Poprad
12	Construcciones y Auxiliar de Ferrocarri-les S. A. (CAF)	44	Texmaco Rail and Engineering Ltd. (TEXRAIL)
13	Corifer SpA	45	CJSC Tikhvin Freight Car Building Plant (TVSZ)
14	CSR Corporation Limited	46	Titagarh
15	CZ LOKO, a.s.	47	Tokyu Car Corporation
16	Diesel Locomotive Works (DLW)	48	OAO Torzhokskiy Vagonostroitelny Zavod (TorVZ) /JSC Torzhok Car Building Plant
17	Downer Edi Rail Pty Ltd (Downer Rail)	49	Toshiba
18	Electro-Motive Diesel (EMD)	50	ZAO Transmashholding
19	FreightCar America	51	Transnet Rail Engineering (TRE)
20	GE Transportation	52	Transtech Oy
21	The Greenbrier Companies	53	Trinity Industries Inc.
22	Hitachi Rail Systems	54	Turkish Locomotive & Engine Industry Inc. (Tülomsas)
23	Hyundai Rotem	55	TÜVASAS
24	Integral Coach Factory (ICF)	56	UGL Rail Ltd. (formerly United Group Rail)
25	IRS Group	57	OAO Uralvagonzavod
26	Kawasaki Heavy Industries, Ltd. Rolling Stock Company	58	Vagonmash
27	Kinki Sharyo Co. Ltd.	59	Voith Turbo
28	Koncar Electric Vehicles Inc.	60	Vossloh AG
29	JSC Kryukovsky Vagonzavod	61	ZOS Vrutky a.s.
30	Legios	62	Wabtec Corporation
31	Mogilyovskij Vagonostroitelnyj Zavod (MVZ)	63	Wagon Pars Co.
32	National Railway Equipment Company (NREC)		

Table 1 The 60 most important rolling stock manufacturers[35]

[35] http://www.sci.de/uploads/tx_edocuments/Marketingkit.pdf

3.4 Rolling stock in India

3.4.1 Dimension of Rolling stock in India

The diagram below is adapted from an IR publication of the 'Schedule of Moving Dimensions'. It shows the 1971 standards for maximum and minimum dimensions of rolling stock.

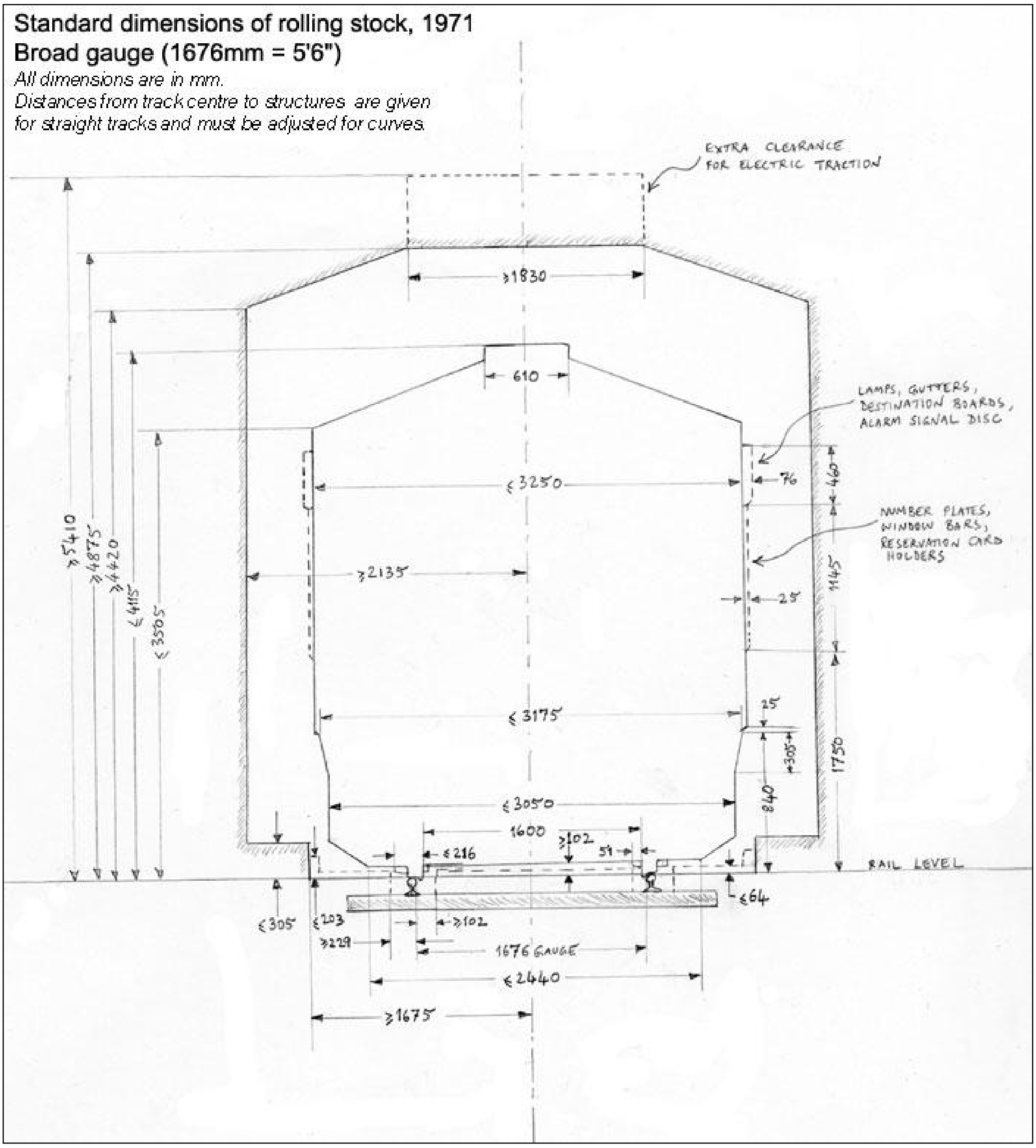

Figure 20 Standard dimensions of rolling stock[36]

[36] http://www.irfca.org/docs/stock-dimensions-1971.html

3.4.2 Locomotives

Figure 21 Two historical steam engines at water refilling station at Agra station[37]

Figure 22 A Beyer Garratt 6594 Engine seen at the National Rail Museum[38]

Locomotives in India consist of electric and diesel locomotives. Biodiesel locomotives are also being used on experimental basis. Steam locomotives are no longer used, except in heritage trains. Locomotives are also called locos or engines. In India, locomotives are classified according to their track gauge, motive power, the work they are suited for and their power or model number. The class name includes this information about the locomotive. It comprises 4 or 5 letters. The first letter denotes the track gauge. The second letter denotes their motive power (Diesel or Electric) and the third letter denotes the kind of traffic for which they are suited (goods, passenger, mixed or shunting). The fourth letter used to denote locomotives' chronological model number. However, from 2002 a new

[37] http://en.wikipedia.org/wiki/Indian_Railways

[38] http://en.wikipedia.org/wiki/Indian_Railways

classification scheme has been adopted. Under this system, for newer diesel locomotives, the fourth letter will denote their horsepower range. Electric locomotives don't come under this scheme and even all diesel locos are not covered. For them this letter denotes their model number as usual.

A locomotive may sometimes have a fifth letter in its name which generally denotes a technical variant or subclass or subtype. This fifth letter indicates some smaller variation in the basic model or series, perhaps different motors, or a different manufacturer. With the new scheme for classifying diesel locomotives (as mentioned above) the fifth item is a letter that further refines the horsepower indication in 100 hp increments: 'A' for 100 hp, 'B' for 200 hp, 'C' for 300 hp, etc. So in this scheme, a WDM-3A refers to a 3100 hp loco, while a WDM-3F would be a 3600 hp loco.

Note: This classification system does not apply to steam locomotives in India as they have become non-functional now. They retained their original class names such as M class or WP class.

As of 31 March 2012, Indian Railways had 5,197 diesel locomotives (increased from 17 on 31 March 1951), 4,309 electric locomotives (increased from 72 on 31 March 1951) and 43 steam locomotives (decreased from 8,120 on 31 March 1951) (see Railway Budget 2012–13 Explanatory Memorandum).

Diesel Locomotives are now fitted with Auxiliary Power Units which saves nearly 88% of Fuel during the idle time when train is not running[39].

3.4.3 Goods wagons or freight cars

The number of freight car or goods wagons was 205,596 on 31 March 1951 and reached the maximum number 405,183 on 31 March 1980 after which it started declining and was 239,321 on 31 March 2012. The number is far less than the requirement and the Indian Railways keeps losing freight traffic to road. Indian Railways carried 93 million tonnes of goods in 1950–51 and it increased to 1010 million tonnes in 2012–13.

However, its share in goods traffic is much lower than road traffic. In 1951, its share was 65% and the share of road was 35%. Now the shares have been reversed and the share of railways has declined to 30% and the share of road has increased to 70%[40].

3.4.4 Passenger coaches

Indian railways have several types of passenger coaches.

Electric Multiple Unit (EMU) coaches are used for suburban traffic in large cities, mainly Mumbai, Chennai, Delhi, Kolkata, Pune, Hyderabad and Bangalore. These coaches numbered 7,793 on 31 March 2012. They have second class and first class seating accommodation.

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[39] http://en.wikipedia.org/wiki/Indian_Railways

[40] http://en.wikipedia.org/wiki/Indian_Railways

Passenger coaches numbered 46,722 on 31 March 2012. Other coaches (luggage coach, parcel van, guard's coach, mail coach, etc.) numbered 6,560 on 31 March 2012[41].

3.4.5 Freight

Indian Railways earns about 70% of its revenues from the freight traffic (Rs. 686.2 billion from freight and Rs. 304.6 billion from passengers in 2011–12). Most of its profits come from movement of freight. It makes a loss on passenger traffic. It deliberately keeps its passenger fares low and cross-subsidizes the loss-making passenger traffic with the profit-making freight traffic.

Since the 1990s, Indian Railways has stopped single-wagon consignments and provides only full rake freight trains for goods. Most of its freight earnings come from movement of bulk goods such as coal, cement, food grains and iron ore in full rakes. It is continually losing freight traffic to road[42].

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[41] http://en.wikipedia.org/wiki/Indian_Railways

[42] http://en.wikipedia.org/wiki/Indian_Railways

3.5 Summary of Rolling stock in India - facts and figures

Rolling stock placed on line during the year is given in the following table:

Type of Rolling Stock	Year	Units placed on line: Replacement account B.G.	M.G.	N.G.	Additional account B.G.	M.G.	N.G.
Diesel Locos	2010-11	47	–	–	149	–	–
	2011-12	59	–	–	157	–	–
Electric Locos	2010-11	81	–	–	179	–	–
	2011-12	49	–	–	264	–	–
Wagons (in vehicle units)	2010-11	635	–	–	16,582@	–	–
	2011-12	778	–	–	12,273$	–	–
	(@ including 6,687 on Deposit A/c) ($ including 5,951 on Deposit A/c)						
Electric Multiple Units:							
Motor Coaches	2010-11	141	–	–	54	–	–
	2011-12	93	–	–	68	–	–
Trailer Coaches	2010-11	227	–	–	178	–	–
	2011-12	246	–	–	76	–	–
Main line Electric Multiple Units:							
Motor Coaches	2010-11	–	–	–	6	–	–
	2011-12	–	–	–	32	–	–
Trailer Coaches	2010-11	–	–	–	18	–	–
	2011-12	–	–	–	96	–	–
Passenger Carriages	2010-11	462	–	–	2,048	–	–
	2011-12	1,276	–	–	1,591	–	–
Other Coaching Vehicles	2010-11	1	–	–	181	–	–
	2011-12	15	–	–	173	–	–

Stock condemned during the year was as under:

Type of Rolling Stock (in units)	B.G. 2010-11	B.G. 2011-12	M.G. 2010-11	M.G. 2011-12	N.G. 2010-11	N.G. 2011-12
Diesel Locos	88	116	24	22	3	–
Electric Locos	42	51	–	–	–	–
Wagons (in Vehicle Units)	7,818	4,972	266	433	1	9
Electric Multiple Units:						
Motor Coaches	77	71	–	–	–	–
Trailer Coaches	144	51	–	–	–	–
Passenger Carriages	879	969	130	76	50	12
Other Coaching Vehicles	102	86	19	4	2	1

INDIAN RAILWAYS ANNUAL REPORT AND ACCOUNTS 2011-12

Figure 23 summary of Indian railways rolling stock[43]

43 http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/pdf/ANNUAL_REPORT_ACCOUNTS_ENG_2011_12/12.pdf

3.5.1 Locomotives

ROLLING STOCK

LOCOMOTIVES

With increasing reliance on dieselisation and electrification, IR has been reducing its fleet of steam locomotives.

NUMBER OF LOCOMOTIVES

	Broad Gauge			Metre Gauge			Total (including NG)		
Year	Steam	Diesel	Elec.	Steam	Diesel	Elec.	Steam	Diesel	Elec.
1980-81	4,361	1,866	1,016	2,763	470	20	7,469	2,403	1,036
1990-91	1,295	2,893	1,723	1,482	731	20	2,915	3,759	1,743
2000-01	–	3,881	2,791	33	657	19	54	4,702	2,810
2010-11	–	4,688	4,033	30	310	–	43	5,137	4,033
2011-12	**–**	**4,776**	**4,309**	**30**	**282**	**–**	**43**	**5,197**	**4,309**

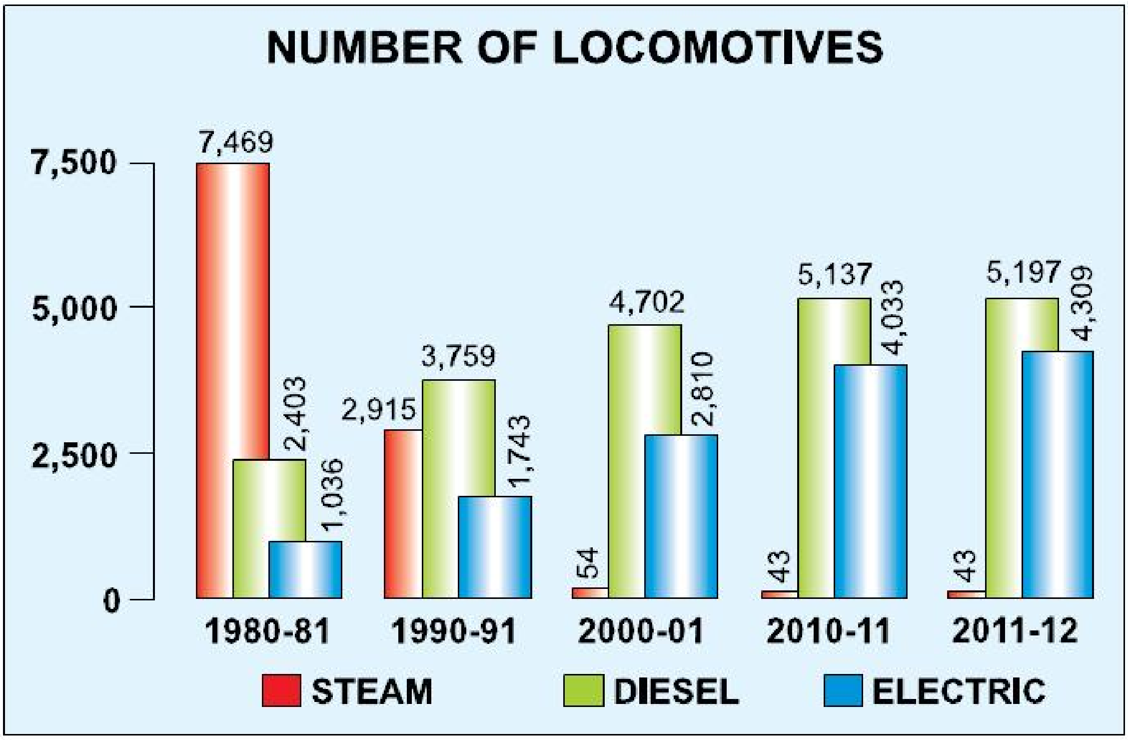

Figure 24 Locomotives in Indian railways [44]

[44] http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/pdf/FACTS_FIGURES_ENG_2011_12/7A.pdf

3.5.2 Goods wagons or Freight cars

FREIGHT CARS/WAGONS

The total number of freight cars including brake vans and railway service wagons in 2011-12 was 239,321.

NO. OF FREIGHT CARS/WAGONS

Year	Broad Gauge	Metre Gauge	Total (incl. N.G.)
1980-81	309,194	86,839	400,946
1990-91	284,362	58,576	346,102
2000-01	205,959	15,294	222,193
2010-11	225,259	4,538*	229,997*
2011-12	**235,009**	**4,112**	**239,321**

* revised

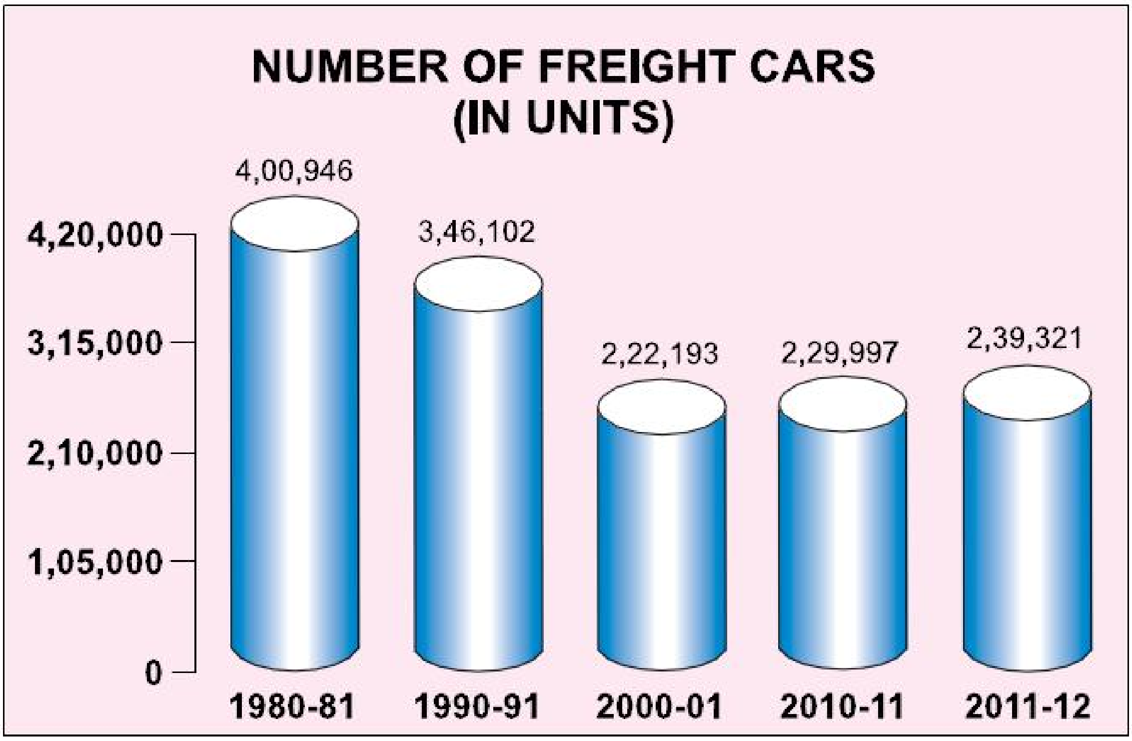

Figure 25 Freight cars in Indian railways [45]

45 http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/pdf/FACTS_FIGURES_ENG_2011_12/7C.pdf

3.5.3 Passenger coaches

PASSENGER COACHES

The number of coaches and their capacity has grown over the years keeping in view the increasing passenger demand.

Year	EMU COACHES# No.	EMU COACHES# Capacity+	CONVENTIONAL COACHES No.@	CONVENTIONAL COACHES Capacity	OTHER COACHING VEHICLES$
1980-81	2,625	500,607	27,478	1,695,127	8,230
1990-91	3,142	609,042	28,701	1,864,136	6,668
2000-01	4,526	859,701	33,258	2,372,729	4,731
2010-11*	7,292	1,364,948	45,082	3,254,555	6,500
2011-12	**7,793**	**1,429,910**	**46,722**	**3,357,145**	**6,560**

+ Includes standing accommodation.
@ Includes rail cars.
$ Includes luggage vans, mail vans etc.
# Includes number of DEMU/DHMU coaches and their capacity.
* revised

Interior view of the AC chair car of the Rajdhani Express

Figure 26 Passenger coaches in Indian railways [46]

[46] http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/pdf/FACTS_FIGURES_ENG_2011_12/7B.pdf

4 Indian Railways[47]

The first railway on Indian sub-continent ran over a stretch of 21 miles from Bombay to Thane. The idea of a railway to connect Bombay with Thane, Kalyan and with the Thal and Bhore Ghats inclines first occurred to Mr. George Clark, the Chief Engineer of the Bombay Government, during a visit to Bhandup in 1843. The formal inauguration ceremony was performed on 16th April 1853, when 14 railway carriages carrying about 400 guests left Bori Bunder at 3.30 pm "amidst the loud applause of a vast multitude and to the salute of 21 guns." The first passenger train steamed out of Howrah station destined for Hooghly, a distance of 24 miles, on 15th August, 1854. Thus the first section of the East Indian Railway was opened to public traffic, inaugurating the beginning of railway transport on the Eastern side of the subcontinent. In south the first line was opened on 1st July, 1856 by the Madras Railway Company. It ran between Vyasarpadi Jeeva Nilayam (Veyasarpandy) and Walajah Road (Arcot), a distance of 63 miles. In the North a length of 119 miles of line was laid from Allahabad to Kanpur on 3rd March 1859. The first section from Hathras Road to Mathura Cantonment was opened to traffic on 19th October, 1875. These were the small’s beginnings which is due course developed into a network of railway lines all over the country. By 1880 the Indian Railway system had a route mileage of about 9000 miles.

4.1 Introduction

The premier transport organization of the country is the largest rail network in Asia and the world’s second largest under one management. Indian Railways is a multi-gauge, multi-traction system covering the following:

Track	**Broad Gauge (1676 mm)**	**Meter Gauge (1000 mm)**	**Narrow Gauge (762/610 mm)**	**Total**
Kilometers	86,526	18,529	3,651	108,706
Route Kilometers	**Electrified**	**Total**		
	16,001	63,028		

Table 2 Kilometers and gauge

Other Interesting facts of Indian Railways

Indian Railways runs around 11,000 trains everyday, of which 7,000 are passenger trains.

47 http://www.indianrailways.gov.in/railwayboard/view_section.jsp?lang=0&id=0,1

locomotives	Coaching vehicles	Freight wagons	Stations
7566	37,840	222,147	6853
Yards	**Good sheds**	**Repair shops**	**Work force**
300 -	2300 -	700 -	1.54 million

Table 3 Other facts of indian railways

Territorial Readjustment of Zones and In-House Reforms

In order to bring about greater efficiency in administration, speedy implementation of on-going projects, better customer care, reduction of workload on General Managers etc., Indian Railways have decided to create seven new zones by territorial re-adjustment of existing zones. The new zones, having limited financial burden on Railways, will have thin and lean, efficient and modern administrative set up. Two of the new zones have already started functioning.

National Rail Vikas Yojana

With a view to complete strategically important projects within a stipulated period of time, a non-budgetary investment initiative for the development of Railways has been launched. Under the scheme all the capacity bottlenecks in the critical sections of the railway network will be removed at an investment of Rs.15,000 crore over the next five years. These projects would include:

1. Strengthening of the golden Quadrilateral to run more long-distance mail/express and freight trains at a higher speed of 100 kmph.
2. Strengthening of rail connectivity to ports and development of multi-modal corridors to hinterland.
3. Construction of four mega bridges - two over River Ganga, one over River Brahmaputra, and one over River Kosi.
4. Accelerated completion of those projects nearing completion and other important projects.

New Steps towards Safety and Security

Safety of 13 million passengers that Indian Railways serve every day is of paramount importance to the system. Over the years, apart from the regular safety norms followed, the network has taken a number of steps through innovative use of technology and stepped up training to its manpower to enhance safety standards. Constitution of Rs.17,000 crore non-lapsable Special Railway Safety Fund (SRSF) to replace the arrears of aging assets of Railways over the next six years has been a historical move in this direction. A number of distressed bridges, old tracks, signaling system and other safety enhancement devices will be replaced during this period. As far as budget allocation for safety is concerned, Rs.1,400 crore was allocated in the revised estimate for the year 2001-02 and Rs.2,210 crores for the year 2002-2003. Extensive field trials of the Anti-Collision Device (ACD), indigenously developed by Konkan Railway, is going on and once deployed across the Zonal Railways, this innovative technology will help railways reduce accidents due to collision between trains.
Security of railway passengers is at present a shared responsibility of the Railway Protection Force (RPF) and the Government Reserve Police (GRP). Efforts are on to amend the Railway Act to give more powers to the RPF in ensuring security of passengers

on trains and within Railway premises. Deployment of women police Force has been made for security and assistance of women passengers.

Improving Financial Health

The financial position of Indian Railways has been slowly but steadily improving. Some of the highlights of the financial performance during 2001-02 include: improved operating ratio from 98.8 per cent to 96.6 per cent, savings in ordinary working expenses of Rs.1,487 crores, Depreciation Reserve Fund (DRF) balance goes up from Rs. 78.04 crores during March last year to Rs.632.99 crores during same time this year. Railways have established a new milestone in incremental freight loading during July this year by carrying 5.70 million tonnes of goods. Freight loading for the last financial year crossed the target and attained 492.31 million tonnes.

New Trends in Passenger Amenities

To take care of the unreserved segment of the passengers, a new pilot project on computer based unreserved ticketing has been launched this year. Of the 13 million passengers served by the network every day, nearly 12 million are unreserved passengers. To cater to this huge segment, computer based ticketing systems has been launched for all stations in Delhi area and in due course throughout the country. With this, unreserved tickets can be issued even from locations other than the boarding station and will reduce crowds at booking offices and stations.

Indian Railway Catering and Tourism Corporation

With the assistance of Centre for Railway Information Systems has launched On-line ticketing facility which can be accessed through website irctc.co.in. Computerized reservation facilities were added at 245 new locations. At present these facilities are available at 758 locations in the country covering about 96 per cent of the total workload of passenger reservation. Computerized Reservation related enquiries about accommodation availability, passenger status, train schedule, train between pair of stations etc.have been made web enabled.
A pilot project for issuing monthly and quarterly season tickets through Automated Teller Machines (ATMs) has been launched in Mumbai this year and has been found very successful. Another pilot project for purchasing tickets including monthly and quarterly season tickets through Smart Card has also been launched.

"National Train Enquiry System" has been started in order to provide upgraded passenger information and enquiries. This system provides the train running position on a current basis through various output devices such as terminals in the station enquiries and Interactive Voice Response System (IVRS) at important railway stations. So far the project has been implemented at 98 stations.

Freight Operations Information System (FOIS)

Computerization of freight operations by Railways has been achieved by implementing Rake Management System (RMS). Such FOIS terminals are available at 235 locations. Railways have established their own intra-net 'Railnet' It provides networking between Railway Board, Zonal Headquarters, Divisional headquarters, Production Units, Training Centers,etc..

Sterling Performance by PSUs

The public sector undertakings of the Railways, especially IRCON and RITES, scored commendable achievements during the last three years. IRCON International has achieved a record turnover of Rs.900 crores during 2001-02 and the foreign exchange earnings of this prestigious organization have increased six fold over the years. At the international level, IRCON is at present executing different projects in Malaysia, Bangladesh and Indonesia. The PSU has registered a strong presence in the international scenario by its sterling track record.

RITES, another prestigious PSU under the Ministry has scaled new heights in performance, profit and dividend to the shareholders during the last three years. Its turnover increased from Rs.172 crores in 1999 to Rs.283 crores in 2002. RITES for its sterling performance secured the prestigious ISO-9001 Certification this year. The company has also entered into export/leasing of locomotives in different countries in Asia and Africa. RITES is operating all over the world including Columbia, UK, Iran, Malaysia, Myanmar, Bangladesh, Sri Lanka, Tanzania, Uganda, Ethiopia, Turkmenistan and Uzbekistan. Indian Railways Finance Corporation Limited secured excellent rating for fourth year in succession by the Department of Public enterprises on the basis of the performance targets. Besides, Standards and Poor's, the international credit rating agency, also reaffirmed the sovereign ratings to IRFC. The Corporation has been making profits and paying dividends.

Indian Railway Catering & Tourism Corporation (IRCTC) Internet based ticket booking has been launched by IRCTC in Delhi, Chennai, Bangalore, Mumbai and Calcutta in 2012. Hygienic and air-conditioned food plazas having consumer-friendly ambience opened at Pune and Chennai and license for similar plazas awarded for 17 more locations. In all, 50 such plazas will be opened by the end of this financial year across the zonal Railways. Railneer - packaged drinking water is to be made available from December 2012. More than half a lakh tourists have availed the value added tour package programme launched by the Corporation in 2012.

Innovative Technologies by Konkan Railway

Konkan Railway Corporation (KRC), the technological marvel of Indian Railways, has invented quite a few new technologies. Anti Collision Device (ACD), state-of-art indigenous technology of KRC is currently under-going intensive field trials and is capable of avoiding collision between trains. Sky bus metro is another innovative, economic and eco-friendly mass rapid transportation solution devised by Konkan Railway. Self Stabilizing Track (SST) devised by KRC, which is undergoing trials at present, will help Railways run the fastest train in the near future and will make tracks much more safe and sustainable.

Private Sector Participation

The participation of both private and public sectors in developing rail infrastructure has gone up. A joint venture company was formed with Pipava Port authorities to provide broad gauge connectivity to Pipava Port. MoUs have been signed between Ministry of Railways and the State governments of Andhra Pradesh, Karnataka, Maharashtra, West Bengal, Tamil Nadu and Jharkhand in developing rail infrastructure in these States.

Telecommunication - New Trends

To give improved telecommunication systems on Railways, Optical Fiber based communication systems has been adopted and laying OFC has increased to 7,700 route kilometer this year. Rail Tel Corporation has been created to make a nationwide broadband multimedia network by laying optical fiber cable along the railway tracks. This system will provide better operational and passenger amenities and additional revenue to Railways.

New Technologies

India became the first developing country and the 5th country in the world to roll out the first indigenously built "state-of-the-art" high horse power three phase electric locomotive when the first such loco was flagged off from Chittranjan Locomotive Works (CLW). CLW has been achieving progressive indigenization and the cost of locomotives has come down to the level of Rs.13.65 crores. Diesel Locomotives Works, Varanasi has produced state-of-the-art 4000 HP AC/AC diesel locomotive in April this year. These locos are capable of hauling 4,800 ton freight trains at a speed of 100 KMPH and can run continuously up to 90 days in one stretch without any major maintenance.

Honors and Awards

Indian Railways achieved a number of recognitions and awards in sports, tourism sector and for excellence in operational matters. In the Common Wealth Games in Manchester, the Indian team’s record performance has been mainly due to Railway team’s excellence in sports. Except one member the entire women’s Hockey team which bagged the gold medal belonged to Railways. Mohd Ali Qamar of Indian Railways has bagged gold medal for boxing and other participants from Railways helped India win medals in many a team events. A number of sportspersons from Railways were conferred with the coveted Arjuna Awards and other major sports awards. Darjeeling Himalayan Railways attained the World Heritage Status from UNESCO. Fairy Queen, the oldest functioning steam engine in the world, which finds a place in the Guinness Book of World Records, got Heritage Award at the International Tourist Bureau, Berlin in March, 2000. On operational front, Delhi Main station entered the Guinness Book for having the world’s largest route relay interlocking system.

Social obligations and care for weaker sections

Senior citizens, students, disabled persons etc. enjoy concessional benefits from Railways. New initiatives in this area during the last three years include reduction of age limits for special concession to senior women citizen from 65 to 60 years, blind and mentally challenged persons can now travel in AC classes on confessional rates. Free second class Monthly Season Tickets (MSTs) for school going children up to tenth standard for travel between home and school was also introduced.

Tie-Up with Foreign Railways

Indian Railways is in constant touch with Railways across the world to bring in state-of-art facilities in its system. Towards this, a Memorandum of Understanding was signed during the Eighth Session of the Indo-Austria Joint Economic Commission held in Vienna. This seeks to promote and deepen long-term infrastructure-specific cooperation between Indian and Austrian Railways to their mutual benefit. A three-day International Conference of Union of Railways was organized by Indian Railways in New Delhi in which hundreds of delegates from various industries and Railways around the world participated.

4.1.1 Organizational structure

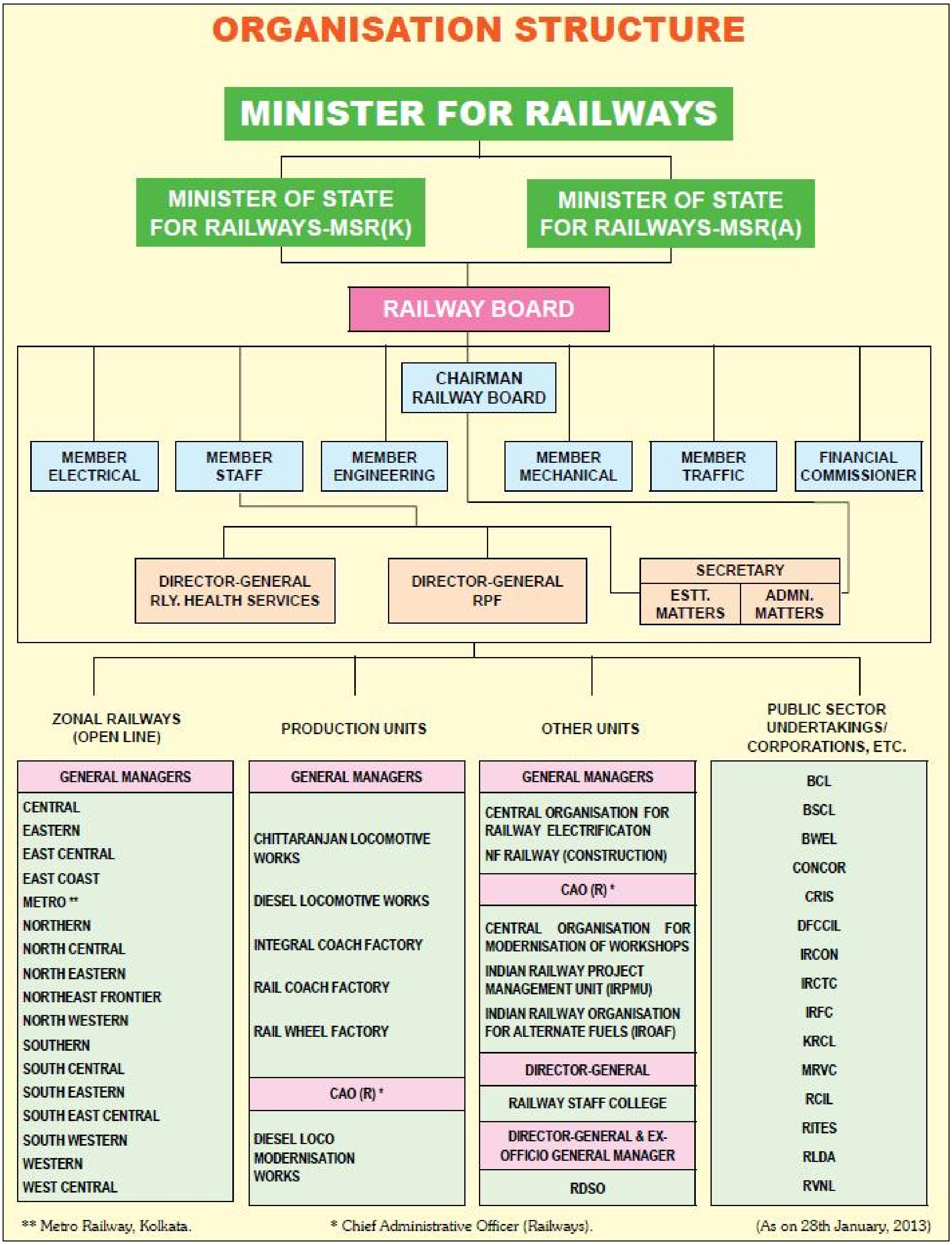

Figure 27 Organisation structure of Indian Railways[48]

[48] http://www.indianrailways.gov.in/railwayboard/view_section.jsp?lang=0&id=0,1,304,305

4.1.2 Board Members/General Managers

MEMBERS OF RAILWAY BOARD			
Chairman Railway Board		Arunendra Kumar	
Member Electrical	Kul Bhushan	Member Staff	A.K. Mital
Member Engineering	S.K. Jain	Member Mechanical	Alok Johri
Member Traffic	D.P. Pande	Financial Commissioner	Rajendra Kashyap
Railway unit		**General manager/Director**	**Service**
Central		S K Sood	IRSME
Eastern		R K Singh (L/A)	IRSEE
Northen		V K Gupta	IRSE
North Eastern		K K Atal	IRSME
N F		R S Virdi	IRSME
N F (CONS.)		R K Singh (L/A)	IRSEE
Southern		Rakesh Mishra	IRSME
South Central		P K Srivastava	IRSEE
South Eastern		Radhey Shyam	IRSE
Western		Hemant Kumar	IRSME
CLW		C P Tayal	IRSE
DLW		B P Khare	IRSE
ICF		A K Agarwal	IRSME
RCF		Pramod Kumar	IRSME
Rail wheel factory		Rajeev Bhargava (L/A)	IRSE
CORE / ALD		JAGDEV KALIA	IRSEE
Metro / Kolkata		Rajeev Bhargava (L/A)	IRSE
RDSO		V Ramchandran	IRSS
NAIR / Vadodara		SMT R Ravi Kumar	IRAS
East central		Madhuresh Kumar	IRSE
East coast		R Vishnoi	IRSME
North central		Pradeep Kumar	IRSE
North western		R C Agarwal	IRSSE
South east central		Navin Tondon	IRSEE
South western		P K Saxena	IRSE
West central		Ramesh Chandra	IRSS
COFMOW (CAO/R)		P K Agarwal HAG	IRSME
D M W (CAO/R)		A K Kansal HAG	IRSME
IRIEEN / NASIK		D Ramaswamy, SAG	IRSEE
IRIMEE / JAMALPUR		S K Pathak, HAG	IRSME
IRICEN / PUNE		C P Tayal, HAG	IRSE
IRISET / SEC.		Satyendra Kumar, HAG	IRSSE
IRITM / LKO		Ms.Ashima Singh, HAG	IRTS
CAMTECH /GWALIOR		A R Tupe, ED / SAG	IRSME

Table 4 Board members[49]

[49] http://www.indianrailways.gov.in/railwayboard/view_section.jsp?lang=0&id=0,1,304,365

4.1.3 Directorates

GAZETTE			
Accounts	Civil Engineering	Coaching	Computerization & Information Systems
Corporate Co-ordination	Economics	Efficiency & Research	Electrical Engineering
Establishment	Finance	Finance (Budget)	Finance(Expenditure)
Health	Infrastructure	Land & Amenities	Legal
LRDSS	Management Services	Mechanical Engg	Mechanical Engg (PU&W)
Official Language	Pay Commission	Planning	Projects
Public Relation	Documents laid in Lok Sabha	Railway Sports Promotion Board	Safety
Secretary Branches	Security	Signal	Statistics & Economics
Stores	Telecommunication	Track	Traffic Commercial
Traffic Transportation	Tourism & Catering	Vigilance	Works
Expert Committee on Railways	Accounting Reforms	IRCA	Expert Committee on ICT
Fast Track Committee	High Power Committee	Secret Ballot Election Committee	

Tabelle 5 Directorates [50]

[50] http://www.indianrailways.gov.in/railwayboard/view_section.jsp?lang=0&id=0,1,304,366

4.1.4 Maps

Figure 28 Map of State and Union Territories of India[51]

[51] http://www.mapsofindia.com/indiamap.html

Figure 29 Travel Map of India [52]

[52] http://www.mapsofindia.com/tourism/

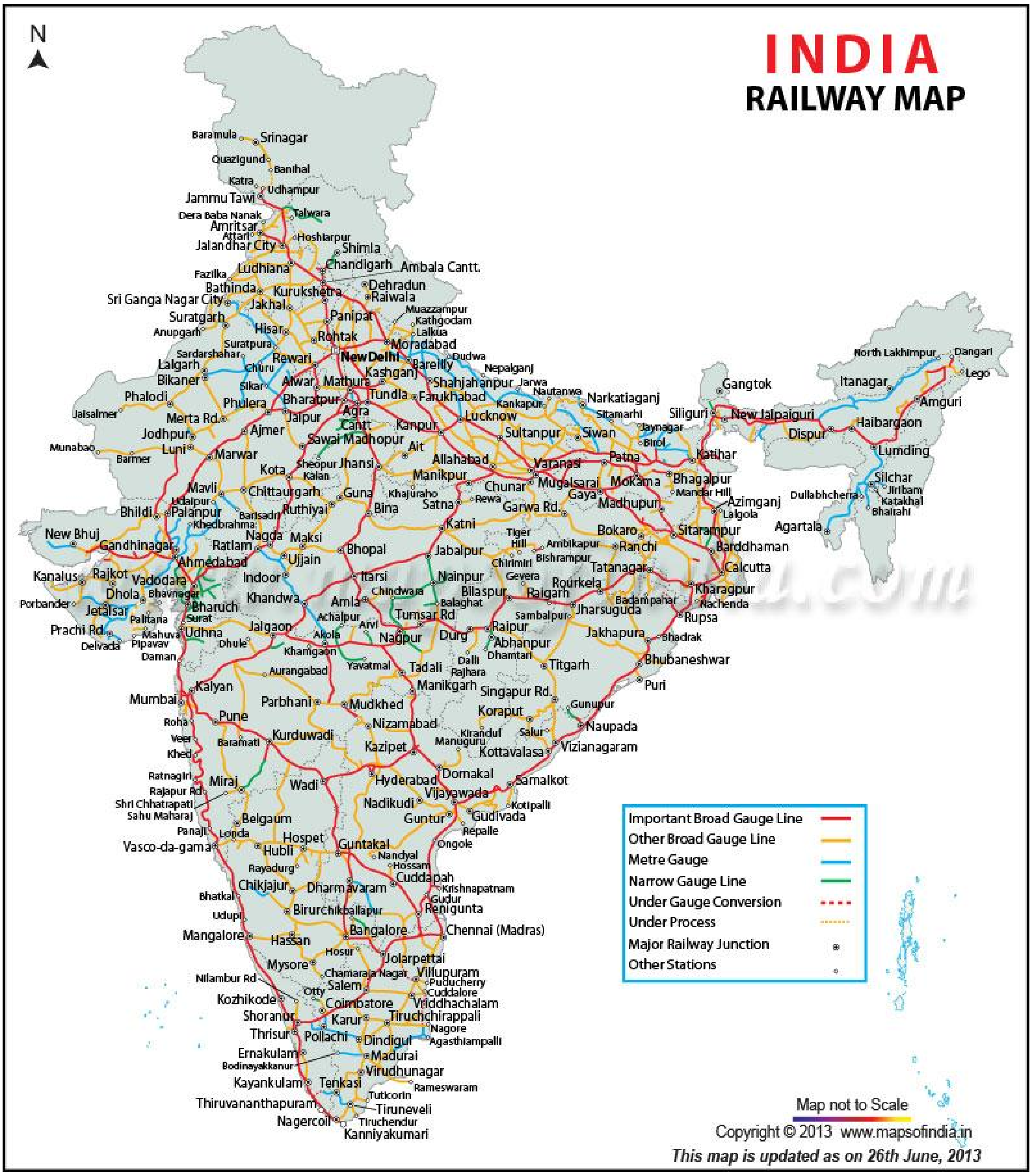

Figure 30 Map of Indian Railways [53]

[53] http://www.mapsofindia.com/maps/india/india-railway-map.htm#

Figure 31 Map of Railway zone [54]

54 http://www.mapsofindia.com/maps/india/railway-zonal-map.html

4.1.5 Railway zones

Indian Railways is divided into several zones, which are further sub-divided into divisions. The number of zones in Indian Railways increased from six to eight in 1951, nine in 1952 and sixteen in 2003 and now seventeen.]Each zonal railway is made up of a certain number of divisions, each having a divisional headquarters. There are a total of sixty-eight divisions.

Zonal railways details

Sl. No.	Name	CODE	Year of Establish-ment	Route KMs	Headquarters	Divisions
1	Central Railway	CR	1951	3905	Mumbai	Mumbai, Bhusawal, Pune, Solapur,Nagpur
2	East Central Railway	ECR	2001	3628	Hajipur	Danapur, Dhanbad,Mughalsarai, Samastipur, Sonpur
3	East Coast Railway	ECoR	2001	2572	Bhubaneswar	Khurda Road,Sambalpur,Visakhapatnam
4	Eastern Railway	ER	1952	2414	Kolkata	Howrah, Sealdah,Asansol, Malda
5	North Cent-ral Railway	NCR	2003	3151	Allahabad	Allahabad, Agra,Jhansi
6	North Eas-tern Railway	NER	1952	3667	Gorakhpur	Izzatnagar, Lucknow,Varanasi
7	North Wes-tern Railway	NWR	2002	5459	Jaipur	Jaipur, Ajmer,Bikaner, Jodhpur
8	Northeast Frontier Railway	NFR	1958	3907	Guwahati	Alipurduar, Katihar,Rangia, Lumding,Tinsuki a
9	Northern Railway	NR	1952	6968	Delhi	Delhi, Ambala,Firozpur, Lucknow, Morada-bad
10	South Cent-ral Railway	SCR	1966	5803	Secunderabad	Secunderabad,Hyderabad,Guntakal, Guntur ,Nanded, Vijayawada
11	South East Central Railway	SECR	2003	2447	Bilaspur	Bilaspur, Raipur,Nagpur
12	South Eas-tern Railway	SER	1955	2631	Kolkata	Adra,Chakradharpur,Kharagpur, Ranchi
13	South Wes-tern Railway	SWR	2003	3177	Hubli	Hubli, Bangalore,Mysore
14	Southern Railway	SR	1951	5098	Chennai	Chennai, Trichy,Madurai, Palakkad,Salem,T hiruvananthapuram
15	West Cent-ral Railway	WCR	2003	2965	Jabalpur	Jabalpur, Bhopal,Kota
16	Western Railway	WR	1951	6182	Mumbai	Mumbai Cent-ral,Ratlam, Ahmedabad,Rajkot, Bhavnagar,Vadodara
17	Kolkata Metro Railway	KNR	2009		Kolkata	Kolkata

Table 6 Zonal Railways details [55]

[55] http://en.wikipedia.org/wiki/Indian_Railways

Each of the seventeen zones is headed by a general manager who reports directly to the Railway Board. The zones are further divided into divisions under the control of divisional railway managers (DRM). The divisional officers of engineering, mechanical, electrical, signal and telecommunication, accounts, personnel, operating, commercial, security and safety branches report to the respective Divisional Manager and are in charge of operation and maintenance of assets. Further down the hierarchy tree are the station masters who control individual stations and the train movement through the track territory under their stations administration.

4.1.6 Recruitment and Training

Staff are classified into gazetted (Group 'A' and 'B') and non-gazetted (Group 'C' and 'D') employees. The recruitment of Group 'A' gazetted employees is carried out by the Union Public Service Commission through exams conducted by it. The recruitment to Group 'C' and 'D' employees on the Indian Railways is done through 20 Railway Recruitment Boards and Railway Recruitment Cells which are controlled by the Railway Recruitment Control Board (RRCB). The training of all cadres is entrusted and shared between six centralized training institutes

4.1.7 Production Units

Indian Railways manufactures much of its rolling stock and heavy engineering components at its six manufacturing plants, called Production Units, which are managed directly by the Ministry. Popular rolling stock builders such as CLW and DLW for electric and diesel locomotives; ICF and RCF for passenger coaches are Production Units of Indian Railways. Over the years, Indian Railways has not only achieved self-sufficiency in production of rolling stock in the country but also exported rolling stock to other countries. Each of these production units is headed by a general manager, who also reports directly to the Railway Board. The production units are:

Name	Abbr.	Year Established	Location	Main products
Jamalpur Locomotive Workshop	JLW	1862	Jamalpur	Diesel/Electric Loco maintenance.
Golden Rock Railway Workshop	GOC	1928	Trichy	Diesel-electric Locomotives
Chittaranjan Locomotive Works	CLW	1947	Chittaranjan, Asansol	Electric Locomotives
Diesel Locomotive Works	DLW	1961	Varanasi	Diesel Locomotives
Diesel-Loco Modernisation Works	DMW	1981	Patiala	Diesel-electric Locomotives
Integral Coach Factory	ICF	1952	Chennai	Passenger coaches
Rail Coach Factory	RCF	1986	Kapurthala	Passenger coaches
Rail Spring Karkhana	RSK	1988	Gwalior	Passenger coach springs
Rail Wheel Factory	RWF	1984	Bangalore	Railway wheels and axles
Rail Wheel Factory	RWF	2012	Chhapra	Railway wheels
Rail Coach Factory, Raebareli	RCF	2012	Raebareli	Passenger coaches

Table 7 Production units[56]

4.1.8 Other subsidiaries

There also exist independent organizations under the control of the Railway Board for electrification, modernization, research and design and training of officers, each of which is headed by an officer of the rank of general manager. A number of Public Sector Undertakings, which perform railway-related functions ranging from consultancy to ticketing, are also under the administrative control of the Ministry of railways.

There are fourteen public undertakings under the administrative control of the Ministry of Railways

- Bharat Wagon and Engineering Co. Ltd. (BWEL)
- Centre for Railway Information Systems (CRIS)[17]
- Container Corporation of India Limited (CONCOR)
- Dedicated Freight Corridor Corporation of India Limited (DFCCIL)
- Indian Railway Catering and Tourism Corporation Limited (IRCTC)

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[56] http://en.wikipedia.org/wiki/Indian_Railways

- Indian Railway Construction (IRCON) International Limited
- Indian Railway Finance Corporation Limited (IRFC)
- Konkan Railway Corporation Limited (KRCL)
- Mumbai Railway Vikas Corporation (MRVC)
- Railtel Corporation of India Limited (Rail Tel)
- Rail India Technical and Economic Services Limited (RITES)
- Rail Vikas Nigam Limited (RVNL)
- Burn Standard and Co. Ltd (BSCL)
- Braithwaite and Co. Ltd (BCL)

4.2 RDSO

4.2.1 Introduction

(Research design and standard organization) All the directorates of RDSO except Defense Research are located at Lucknow.Cells for Railway Production Units and industries, which look after liaison, inspection and development work, are located at Bangalore, Bharatpur, Bhopal, Mumbai, Burnpur, Kolkata, Chittaranjan, Kapurthala, Jhansi, Chennai, Sahibabad, Bhilai and New Delhi.

Railways were introduced in India in 1853 and as their development progressed through to the twentieth century, several companies managed, systems grew up. To enforce standardization and co-ordination amongst various railway systems, the Indian Railway Conference Association (IRCA) was set up in 1903, followed by the Central Standards Office (CSO) in 1930, for preparation of designs, standards and specifications. However, till independence, most of the designs and manufacture of railway equipments was entrusted to foreign consultants. With Independence and the resultant phenomenal increase in country's industrial and economic activity, which increased the demand of rail transportation a new organization called Railway Testing and Research Centre (RTRC) was setup in 1952 at Lucknow, for testing and conducting applied research for development of railway rolling stock, permanent way etc.

Central Standards Office (CSO) and the Railway Testing and Research Centre (RTRC) were integrated into a single unit named Research Designs and Standards Organization (RDSO) in 1957, under Ministry of Railways at Lucknow.
The status of RDSO has been changed from an 'Attached Office' to 'Zonal Railway' since 01.01.2003.

4.2.2 Organisation

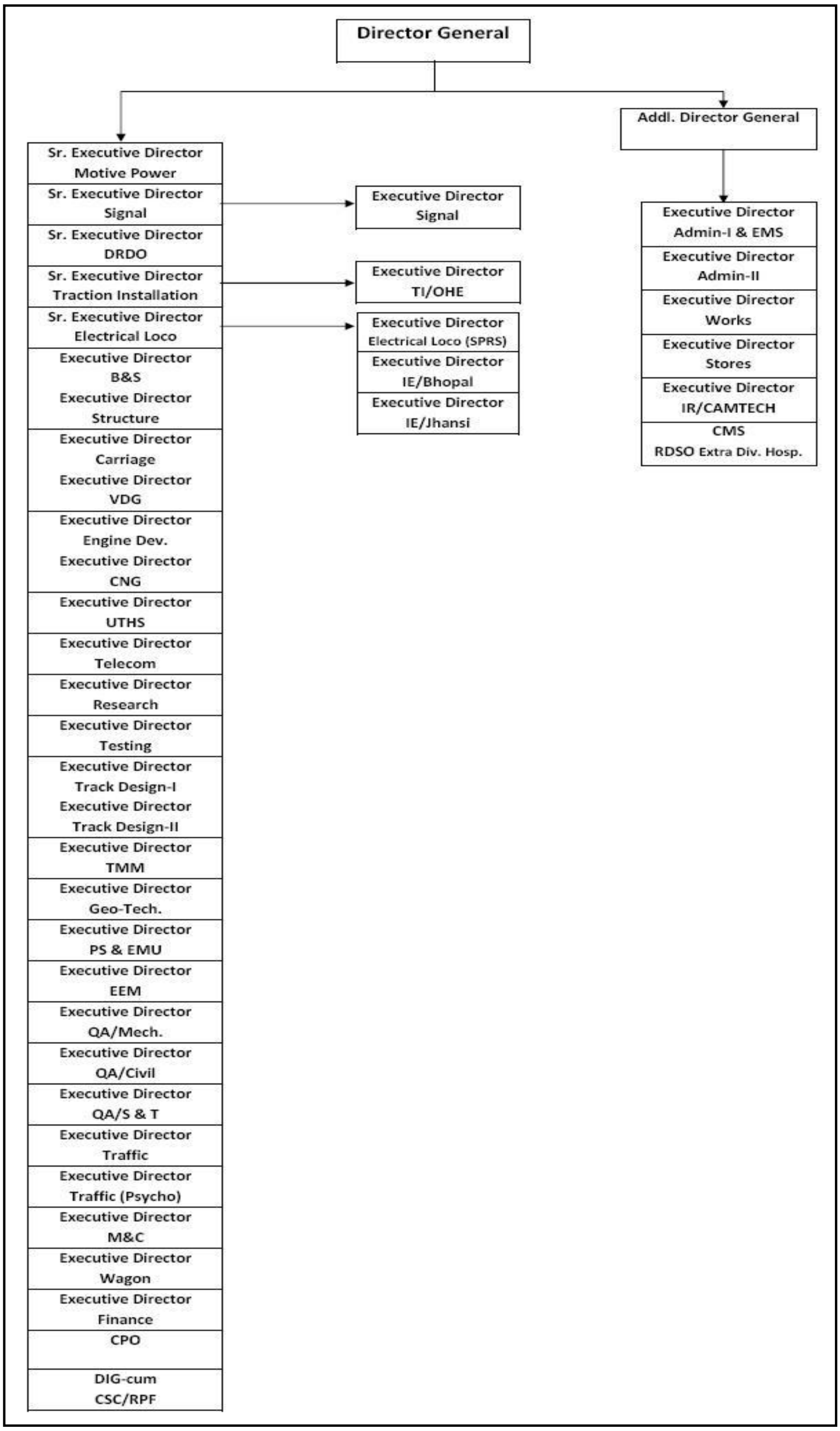

Figure 32 Organisation structure of RDSO[57]

[57] http://www.rdso.indianrailways.gov.in/view_section.jsp?lang=0&id=0,1

4.2.3 Vision

To develop safe, modern and cost effective Railway technology complying with Statutory and Regulatory requirements, through excellence in Research, Designs and Standards and Continual improvements in Quality Management System to cater to growing demand of passenger and freight traffic on the railways.

4.2.4 Central Board of Railway Research

Board of Railway Research (CBRR) consist of DG/RDSO as Chairman, Addl. Member (Civil Engg.), Addl. Member (Mechanical Engg), Addl. Member (Elect.), Addl. Member (Sig), Addl. Member (traffic), Advisor (Finance), Executive Director (E&R), Executive Director (Plg.)/Railway Board as members and Addl. Director General/RDSO as member secretary. Non- Railways members of CBRR consist of eminent scientists, technologists, engineers and senior executives of other research organizations, academic institutions and industrial units related to railway technology and materials. Functions of CBRR are:

- To consider and recommend the programme of research on Indian Railways.
- To review the research programme from time to time.
- To ensure coordination and assistance from other research laboratories.
- To review the ongoing projects from the technical angle.

4.2.5 Functions

RDSO is the sole R&D organization of Indian Railways and functions as the technical advisor to Railway Board Zonal Railways and Production Units and performs the following important functions:

- Development of new and improved designs.
- Development, adoption, absorption of new technology for use on Indian Railways.
- Development of standards for materials and products specially needed by Indian Railways.
- Technical investigation, statutory clearances, testing and providing consultancy services.
- Inspection of critical and safety items of rolling stock, locomotives, signaling & telecommunication equipment and track components.

RDSO multifarious activities have also attracted attention of railway and non-railway organizations in India and abroad.

4.2.6 Quality policy

To develop safe, modern and cost effective Railway technology complying with Statutory and Regulatory requirements, through excellence in Research, Designs and Standards and Continual improvements in Quality Management System to cater to growing demand of passenger and freight traffic on the railways.

QUALITY ASSURANCE, the quality assurance function in respect of vendor approval and purchase inspection of these items including publication of vendor directories was being looked after by individual technical directorates of RDSO along with their normal functions of research, development and standardization. To impart greater thrust to quality assurance, Railway Board has approved the creation of a separate Quality Assurance Organization at RDSO in Sept. 2002 for Technical disciplines i.e. Mechanical Engg. Including M&C, Civil Engg., S&T & Electrical Engg. Each headed by Executive Director under the overall charge of an HAG officer. With the creation of this Quality Assurance Organization, focused attention and close monitoring of vendor approval and purchase inspection activities is being given[58].

4.3 Track gauge in India

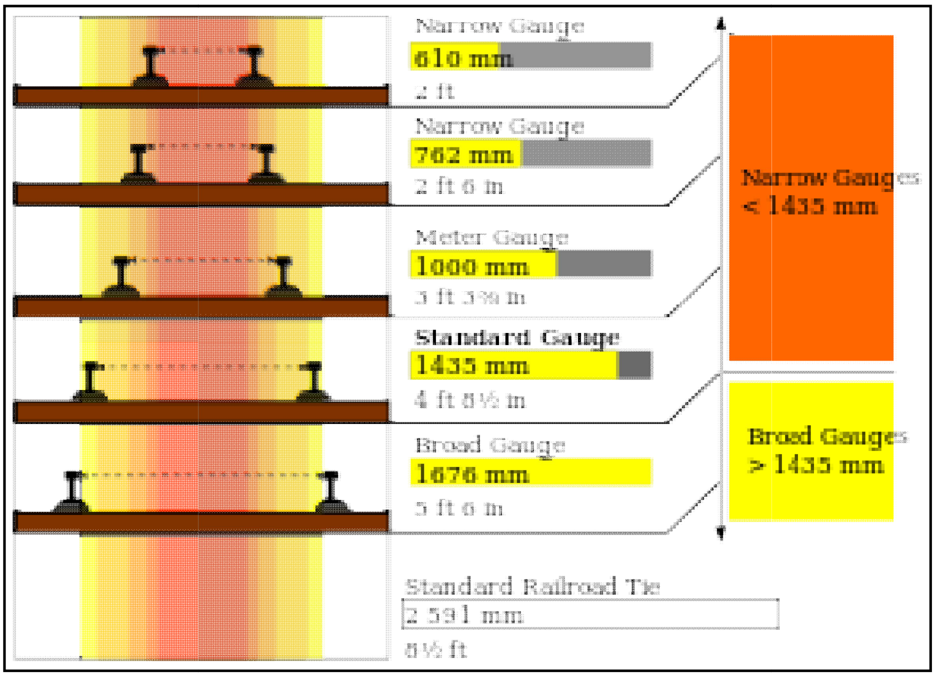

Figure 33 Track gauge in India[59]

Comparison of different gauges common in India with the standard gauge, which is not common in India

Rail gauge in India is complicated by historical usage of multiple track gauges. Indian Railways uses four: 1,676 mm (5 ft 6 in) Broad Gauge (BG), which is also called Indian gauge, 1,000 mm (3 ft 3 3⁄8 in) meter gauge (MG), 762 mm (2 ft 6 in) Narrow Gauge (NG), and 610 mm (2 ft) Narrow Gauge. Project Uni gauge seeks to standardize the rail gauges in India by converting most of the MG and NG tracks to BG track. Some NG tracks on which heritage trains run in hilly regions to Shimla, Darjeeling, Ooty, Kangra, and Matheran will not be converted. Delhi Metro Rail Corporation has constructed 1,435 mm (4 ft 8 1⁄2 in) Standard Gauge (SG) in Delhi and started running metro trains in Delhi city in 2010. However, Delhi Metro is a separate urban mass rapid transit system not owned by Indian Railways.

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[58] http://www.rdso.indianrailways.gov.in/view_section.jsp?lang=0&id=0,1

[59] http://en.wikipedia.org/wiki/Track_gauge_in_India

Overview

BG is the most widely used rail gauge in India with approximately 102,000 km (63,000 mi) of track length and 54,600 km (33,927 mi) of route length in 2011. In some regions MG is common for historical reasons and consists of 7,500 km (4,660 mi) of route length. Narrow gauges are present on a few routes lying in hilly terrains and in some private railways because of cost considerations. Narrow gauges covered a total of 2,400 km (1,491 mi) route length in 2011. Nilgiri Mountain Railway, Darjeeling Himalayan Railway, Kalka-Shimla Railway, Kangra Valley Railway, and Matheran Hill Railway are notable hill lines that use NG.

Broad Gauge

The Governor-General of India in the 1850s chose BG for India rather than the SG. The two main reasons given were greater stability during periods of high wind and unpredictable weather and greater space between the wheels for bigger inside cylinders (although this ceased to be a problem when outside cylinders were introduced). The inability to source standard equipment was not seen to be a problem or was overlooked. The extra cost of longer sleepers was not considered to be a problem, though later the cost saving of shorter sleepers with MG was considered to be an advantage.

Standard Gauge

Small lengths of SG have existed in India for individual projects and short line lengths. The only surviving example was the Kolkata (Calcutta) tram system until 2010 when Delhi Metro Rail Corporation started metro train on 18.5 km-long SG track on Mundka-Inderlok-Kirti Nagar sections and on Central Secretariat-Badarpur sections.

Meter Gauge

In the 1880s, when the BG tracks had been laid over some routes, another Governor-General considered the introduction of infill MG lines to reduce the cost.

Narrow Gauge

Narrow gauges are present on a few routes lying in hilly terrains and in some private railways because of cost considerations. Narrow gauges covered a total of 2,400 km (1,491 mi) route length in 2011. NG railway tracks were constructed for cost considerations, and because simpler engineering permitting sharp turns in hilly regions. The argument was that if money could be saved building MG, then presumably more money could be saved by building NG. The design process during construction was taken to its extreme, with the gauge being carefully chosen to optimize costs for the traffic offering. The result being that each line might be a different gauge, even if it would have been more useful to have a through service[60].

[60] http://en.wikipedia.org/wiki/Track_gauge_in_India

5 Homologation of railway vehicle in Europe

The model split in today's European traffic is in clear contrast to the challenges of the future; the forecasted increase of transport volume of over 40% in the passenger and 70% in the freight sector until 2020 with a strong incline of international traffic can only be mastered economically and ecologically if the share of the railways grows significantly beyond the current value of 8%.
For this reason the European community decided to strengthen the position of the rail by building up the legal and administrative framework to enhance interoperability, liberalisation and competition in the railway sector e.g. the TSI (technical specifications for Interoperability). Unfortunately these prerequisites are not yet finished. The railway operators still are facing many technical, operational and also political barriers for the international use of their rolling stock when building up border-crossing connections. The homologation of a locomotive in a foreign country typically lasts two to four years and costs up to 8 million Euros because the "admission loop" has to be run through various times, as mentioned in the figure below. For passenger trains life the German high speed train ICE the procedure even takes much longer and is many times more expensive[61].

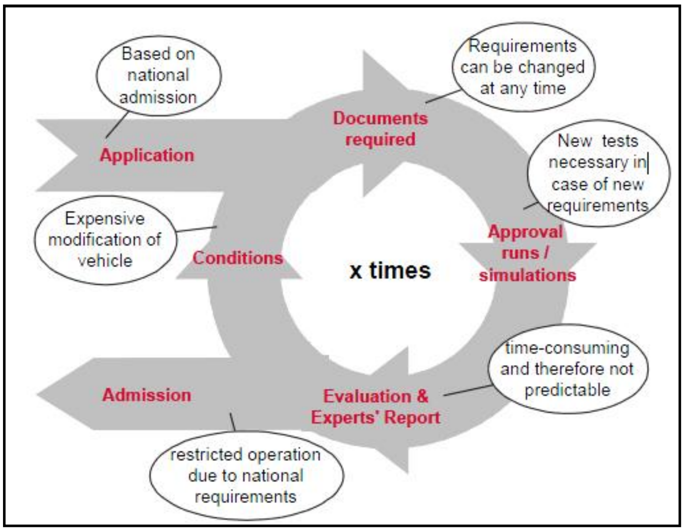

Figure 34 Admission loop[62]

To ensure the railways competitiveness the rolling stock manufacturer and the owner have to minimise investment costs of multi system rolling stock in order to keep cross border traffic cost efficient.

Integrated approach In the European process of harmonization different parties are involved with different interests.

[61] http://www.uic.org/cdrom/2006/wcrr2006/pdf/776.pdf Technical paper- Page1

[62] http://www.uic.org/cdrom/2006/wcrr2006/pdf/776.pdf Technical paper- Page1

Figure below shows only the stakeholders which have direct influence on the actual and future process of interoperable rolling stock.

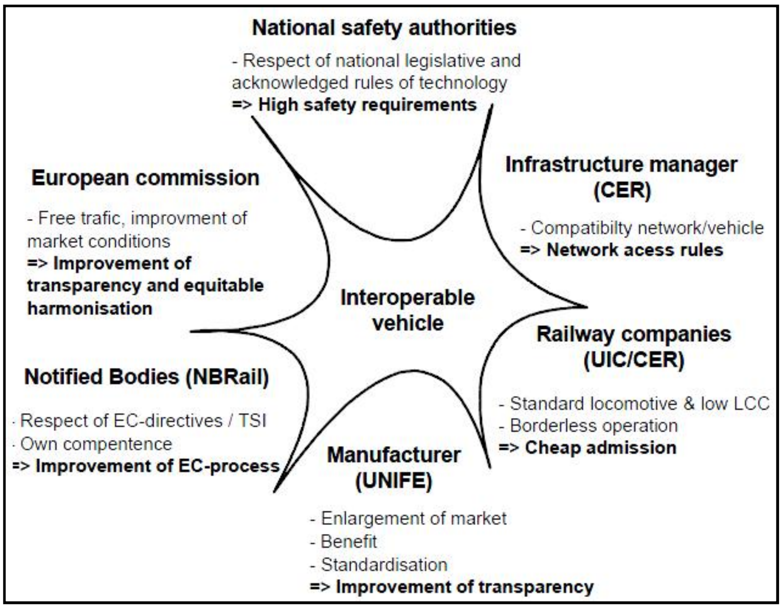

Figure 35 Stake holder in the European homologation process of Rolling stock[63]

German rail has identified the importance of being involved in the development of future harmonization. Therefore DB uses its possibilities to frame the future conditions for interoperable rolling stock. Within the DB, Board division SYSTEMVERBUND BAHN (integrated system rail) has enlarged and bundled the already existing activities in the field of committee work (e.g. creation /modification of the German standards DIN). The cooperation with each of the above mentioned stake holders are an important part of the harmonisation work.

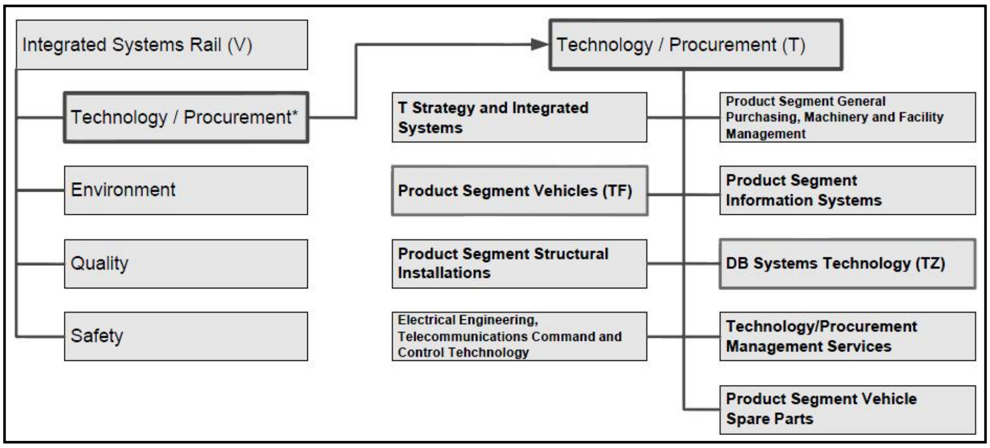

Figure 36 Board Division "integrated system rail" and structure of division "technology / procurement"[64]

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[63] http://www.uic.org/cdrom/2006/wcrr2006/pdf/776.pdf Technical paper- Page 2

[64] http://www.uic.org/cdrom/2006/wcrr2006/pdf/776.pdf Technical paper- Page 3

This “integrated approach” includes amongst others the following activities see below figure)

- Analysis of the state of the art of homologation processes in “Key countries”
- Building up of an integrated homologation strategy with the standardized internal processes
- Observation of developments and influencing of homologation processes
- Application of a knowledge base which ensures DB’s contribution for generating harmonized international specifications and standards (EN, TSI)
- Coordination and cooperation in harmonization projects as MODTRAIN and MODBRAKE
- Delegation of railway experts to the European railway agency (ERA)
- Committee work in the European boards of the International Union of Railways (UIC) and the community of European Railways (CER)
- Elaboration of proposals for future admission processes

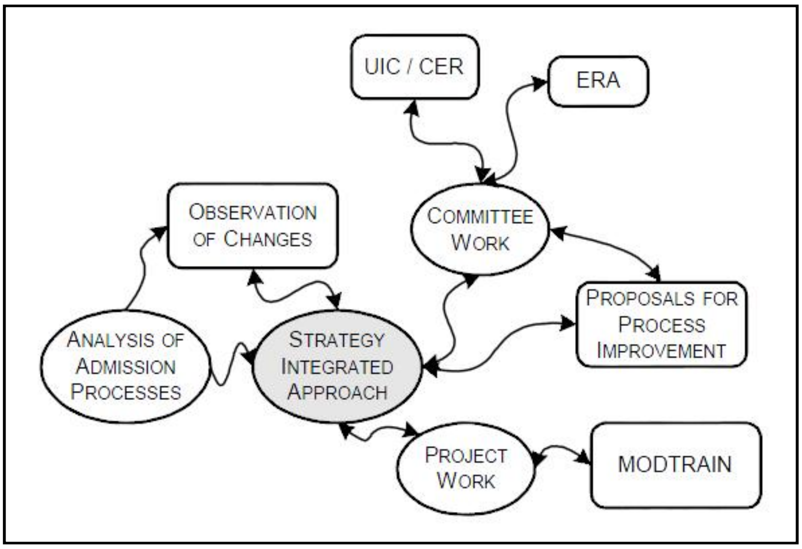

Figure 37 Integrated approach of DB[65]

The focus lies on the analysis of the national homologation procedure, development of a homologation strategy (using “cross-acceptance” where possible etc.), management of the homologation process including testes and reports (following standardized processes), and finally the feedback of experiences and the application of a knowledge base which ensures DB’s contribution for generating harmonized international specifications and standards (EN, TSI).

Homologation strategy – Homologation management

With regards to the examples mentioned above it is clear that a strong project management with high expertise in technology and admission procedure is needed for successful admission. In the case of DB locomotives homologation, the technical project leader of DB technology/procurement division (dep. Vehicles) guided the process. The

[65] http://www.uic.org/cdrom/2006/wcrr2006/pdf/776.pdf Technical paper- Page3

manufacturer's role was limited to a support with manpower, technical documentation and modifications of the construction.

This role allocation is about to change, because the interoperability of a locomotive can be seen as a unique selling proposition (USP). Therefore the industry set up special "homologation divisions" or similar means in order to concentrate know-how and manpower. The locomotives are offered "homologation inclusive" i.e. the activities are coordinated by the manufacturer itself.

Despite of this development, DB itself set up its own homologation activities for three main reasons:

- A strong homologation management still must be coordinated by the operator itself. Not only the locomotive must be approved by the national authority but all parties must be involved e.g. the infrastructure manager (specific access rules)
- A "neutral" position being independent from industry's commercial interests is indispensable for the operator to avoid costly changes of the rolling stock (in favor of an "easy" admission process, where each requirement may be readily accepted).
- Already existing, "old" locomotives and rolling stock is increasingly used in trans-order traffic, especially diesel e.g. class 232 and 241(Poland, Belgium, Netherlands)
- A big part of the measurement know-how needed for homologation still lies within the railway companies.

Therefore the DB technology/purchase division defined responsibilities and competences. For instance, a central department of acknowledges experts (TZK) has been created, where every test campaign is coordinated. Additionally, this department can execute the conformity check in relation to the TSI, e.g. of interoperability constituents. The coordination of a complete vehicle's admission i.e. the project management is done by the product segment vehicle (TF) which combines the management parts of technology and procurement.

In order to fulfill the requirements of the quality standards ISO 9001:2000 certification, a process scheme has recently been created involving every partner. The first application of this procedure is the approval of French high speed train TGV-POS which will be operated in France and Germany. In the context of a close cooperation between the two railways SNCF and DB, the latter took the management for the admission in Germany.

Committee wok

As mentioned in the introduction, DB integrated systems Rail is involved in various committees in connection with the harmonization of rolling stock's requirements. Experts especially out of the Technology/procurement division are delegated to contribute DB's experience and point of view to committees such as the CEN/CENELEC (European committee for standardization/ Eelectrotechnical standardization).

Actually, the focus lies on the creation and renewal of the TSI, e.g. the second issue of the TSI rolling stock high speed. The work of the specialists for the vehicles is coordinated via agents who permanently supervise the development of the TSI: For instance, the possible change of the scope of a TSI (e.g. TSI rolling stock, formerly only high speed train sets, now also locomotives with a speed of 190km/h and more) must be carefully noted.

Experts also are delegated to the European railway agency (ERA), which recently has received the mandate for developing the TSI and, common safety targets, methods and requirements. Contributing to this board is rather important. Actually, DB's chairman of the Board of Directors has been called as representative for the railway undertakings. Key task is the coordination of contributions to new or revised European standards in order to allow their application for the TSI. TSI needs standards of high quality for design, manufacturing and assessment of railway products. The success of the European commission's interoperability and safety directives has to be demonstrated by a significant increase of the railways market share. Therefore TSI and its underlying standards shall serve the economic benefit of the railways, which are the far safest traffic system compared with any other competitor. The transformation of UIC-leaflets in EN will support this approach a lot[66].

5.1 General Principles for approval procedure in European norms[67]

Any approval of a railway vehicle from a dynamic behavior point of view shall be based on either an on-line running test or a numerical simulation using a procedure defining:

- the track geometric quality characteristics,
- the vehicle characteristics,
- the operating conditions and the characteristics of the zones:
    - on tangent track,
    - in large radius curves,
    - in medium radius curves,
    - in small radius curves,
    - in very small radius curves
- the condition of the vehicle to be considered (empty, loaded...)

The railway vehicle shall be approved for each operating category in which it shall be used, e.g. high speed line at V_{lim} = 300 km/h, conventional line at V_{lim} = 200 km/h.

According to the nature of the approval procedure which may be an extension to the approval, the procedure to be applied will be termed as:

- full, taking into account all running conditions and all vehicle conditions,
- partial, if only part of these conditions are taken into considaration.

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[66] http://www.uic.org/cdrom/2006/wcrr2006/pdf/776.pdf Technical paper- Page6, page7

[67] UIC 518 4th Edition, September 2009

In order to carry out this procedure, there is a need to apply a method which is known as:

- "normal" if the individual wheel/rail interaction forces Y and Q are measured and the Y/Q ratio is calculated, as well as the overturning criterion η for category IV vehicles,
- "simplified" if only H forces and/or accelerations on the wheel sets, bogie frame and body are to be measured.
- numerical simulation as for the normal method.

5.2 Choice of the method to be applied[68]

5.2.1 General

The approval of a vehicle will be requested in one of these two situations:

- the vehicle concerned is new, in which case this is the first approval process,
- the vehicle has been altered or is to be operated differently, in which case it becomes an extension to the approval.

Vehicles may fall in one of these three categories:

- "conventional" vehicles if they are of conventional design and subject to usual operating arrangements,
- "new-technology" vehicles,
- "special" vehicles which are either unique or found in low numbers and belong to either of the following classes:

a. track-maintenance vehicles, including re railing vehicles,
b. special transport stock.

Special vehicles may be bespoke to their duties by having multi-bogie/axle configurations, novel suspensions or running gears. The multi-bogie/axle configuration may be an arrangement of more than two axles per vehicle, two or more bogies with different number of axles per vehicle, vehicles with retractable running gear/bogie or articulated parts with bogies/axles. The structure may be formed by component parts of the vehicle that may change inter-relative distance or height, or change wheel configuration depending on the different modes of operation either in a train or in a working mode. The physical properties governing running dynamics may be very different in each of these modes with regard to centre of gravity, distance between wheels both overall (wheel-base) and in bogies, weight distribution, axle load, interconnecting stiffness etc.

With this type of design characteristics a special vehicle could be considered as a "new-technology vehicle" and shall in this case be tested as such.

If the vehicle can be considered "special" due to its use but "conventional" due to its design it shall be tested in the conditions stated hereafter for special vehicles.

[68] UIC 518 4th Edition, September 2009

The selection of the method to be applied, i.e. normal, simplified or numerical simulation, is illustrated by the flowchart in Appendix A.

5.2.2 Approval of a new vehicle

In this case, the full procedure as well as the normal measuring method shall be applied.

However, if the vehicle complies with the requirements set out in point 5.3, a simplified measuring method may be applied except for new-technology vehicles which shall be subject to the full procedure and the normal measuring method.
If the conditions of point 5.4 are met, the procedure for numerical simulations can be applied.

Special cases for standardised freight wagons are addressed in point 5.5.

5.3 Conditions for application of the simplified methods[69]

5.3.1 General

Simplified measuring methods have been developed, based on the experience gained by railways with conventional vehicles. They are based on:

- the measurement of H forces on the wheel sets with accelerations being measured on the vehicle body ($\ddot{y}^*$ and $\ddot{z}^*$),

- the measurement of accelerations on the bogie frame ($\ddot{y}^+$) above the outer axles, and on the body (y* and z*) for bogie vehicles,

- the measurement of accelerations on the wheel sets ($\ddot{y}$) and on the body ($\ddot{y}^*$ and $\ddot{z}^*$) for non-bogie vehicles.

Whenever H forces are measured on a bogie vehicle of whichever type, lateral accelerations ($\ddot{y}^+$) are to be measured on the bogies, especially on the non-instrumented bogies so as to check their dynamic behaviour.

Accelerations on the vehicle body are usually measured above the wheel sets or the bogie pivots.
If the vehicle's geometrical design is strongly dissymmetrical or if masses are not well distributed, accelerations should then be measured at the ends of the vehicle body.

NB: The measurement of $\ddot{y}^*$ and $\ddot{z}^*$ with the filtering defined in Appendix F of UIC 518: 2009, will make it possible to give assessment quantities for running safety ($\ddot{y}_s^*$ and $\ddot{z}_s^*$) replacing the measurement of wheel/rail forces, as well as assessment quantities for running behaviour $\ddot{y}_q^*$ and $\ddot{z}_q^*$

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[69] UIC 518 4th Edition, September 2009

5.3.2 General Conditions

Speed and cant deficiency:

- locomotives: $V_{lim} \leq 160$ km/h and $I_{adm} \leq 150$ mm
- multiple units: $V_{lim} \leq 160$ km/h and $I_{adm} \leq 165$ mm

  160km < $V_{lim} \leq 200$ km/h and $I_{adm} \leq 150$ mm
- passenger vehicles: $V_{lim} \leq 200$ km/h and $I_{adm} \leq 150$ mm
- freight wagons and special vehicles: $V_{lim} \leq 120$ km/h and $I_{adm} \leq 130$ mm

Axle load:

- conventional vehicles: $P_0 \leq 200$ kN
- special vehicles: $P_0 \leq 225$ kN

5.3.3 Specific conditions

In addition to the general conditions to be met, the following provisions shall apply:

5.3.3.1 Conventional vehicles

Powered vehicles:

- locomotives with 2-axle bogies as a maximum:

  $V_{lim} \leq 120$ km/h: measurement of accelerations on the body and bogies

  120 km/h < $V_{lim} \leq 160$ km/h: measurement of H forces and of accelerations on the body
- locomotives with 3-axle bogies: measurement of H forces and of accelerations on the body.
- electric/diesel multiple units including railcars:

  bogie mass ≤10t: $V_{lim} \leq 200$ km/h: measurement of accelerations on the body and bogies

  bogie mass > 10t: $V_{lim} \leq 120$ km/h: measurement of accelerations on the body and bogies

  120 km/h < $V_{lim} \leq 160$ km/h: measurement of H forces and accelerations on the body
- shunting engines (shunting engines with axles):

$V_{lim} \leq 100$ km/h: measurement of accelerations on the vehicle body.

Passenger vehicles:

- vehicles fitted with 2 two-axle bogies

  $V_{lim} \leq 200$ km/h: measurement of accelerations on the body and bogies

- non-bogie vehicles:

  $V_{lim} \leq 120$ km/h: measurement of accelerations on the vehicle body.

Freight wagons:

- non-bogie wagons,
- wagons with 2-axle bogies,
- articulated vehicles comprising several units, with axles or 2-axle bogies:
  - measurement of accelerations on body and wheel sets for non-bogie wagons
  - measurement of accelerations on body and bogies for bogie wagons
- wagons with 3-axle bogies,
- articulated vehicles comprising several units, with 3-axle bogies:
  - measurement of H forces and accelerations on the vehicle body.

5.3.3.2 Special vehicles

Non-bogie vehicles or vehicles with 3-axle bogies as a maximum:

- measurement of accelerations on body and wheel sets for non-bogie vehicles,
- measurement of accelerations on body and bogies for bogie vehicles.

Vehicles with more than 3-axle bogies:

- measurement of H forces on the wheel sets in the most unfavorable position and of accelerations on the vehicle body.

5.4 Conditions for application of numerical simulations[70]

Three areas of application have been identified for numerical simulations. These are:

- approval of vehicles following modification,
- approval of new vehicles by comparison with an already approved "base" design,
- supplement the range of test conditions when the full test programme has not been completed.

The scope of these areas of application and the conditions for use of numerical simulations are described in the following sub-sections.

5.4.1 Modifications of an existing vehicle

When an existing vehicle, or vehicle fleet, is modified then it may be appropriate to use numerical simulations, rather than track testing, to demonstrate that the modifications do not adversely affect the dynamic behaviour of the vehicle.

Vehicle modifications may be carried out for a number of different reasons, for example:

- change of use of the vehicle,
- upgrade of the vehicle,
- modification to improve the behaviour.

In order to approve a modified vehicle by use of numerical simulations, in place of dynamic testing on track, the following conditions must be satisfied:

- the modifications must be within the ranges defined in Appendix B of UIC 518 version 2009 for use of simulations,
- the application of the modified vehicle must be similar to the original vehicle as defined in Appendix B of UIC 518 version 2009,
- test results for the original vehicle must be available for model validation. These tests must include an adequate range of track conditions, curves, cant deficiency, contact conditions etc.
- track data must be available from the original tests to enable validation to be undertaken.

If a vehicle has been tested, according to UIC Leaflet 518, and found to exceed some of the limit values for track fatigue or running behaviour, then it may be appropriate to use numerical simulations to demonstrate that modifications to the vehicle will improve the behaviour sufficiently to meet the limits. The conditions above must be satisfied and the limit values must have been met for the safety parameters.

[70] UIC 518 4th Edition, September 2009

A numerical model of the original vehicle shall be developed and validated against the test results for that vehicle, in accordance with Appendix K -page 90. The modifications shall then be made to the model and the dynamic behaviour simulated and the results compared to the limit values.

Limited tests on the actual modified vehicle must be undertaken to confirm that the modifications have been correctly applied to the model. The tests required will depend on the type of modification being undertaken but may include:

- wheel load and load distribution,
- static tests on the full vehicle,
- slow speed / quasi-static tests,
- laboratory tests of components,
- limited on-track tests, for example vehicle body accelerations,

5.4.2 Comparison with a base design

Where new vehicles are being introduced which are similar to existing vehicles then it may be appropriate to use numerical simulations, rather than track tests, to demonstrate that the behaviour of the new vehicles is satisfactory.

Where new vehicles are being introduced with a range of different types within the fleet (e.g. multiple units with motor bogies, trailer bogies etc.) then it may be appropriate to define one vehicle type as the "base" design, for which a full set of tests is carried out, and approve the other vehicle types by reference to the "base" design.

A "base" design of vehicle must be identified which has been demonstrated to be satisfactory by testing according to UIC Leaflet 518 with $\lambda \geq 1,1$.

The following conditions must also be satisfied:

- the changes from the "base" design must be within the ranges defined in Appendix B of UIC 518 version 2009 for use of simulations,
- the application of the new vehicle must be similar to the "base" design as defined in Appendix B of UIC 518 version 2009,
- test results for the "base" vehicle must be available for model validation. These tests must include adequate range of track conditions, curves, cant deficiency, contact conditions etc.
- track data must be available from the original tests to enable validation to be undertaken.

A numerical model of the "base design" vehicle shall be developed and validated against the test results for that vehicle, in accordance with Appendix K of UIC 518 version 2009. Models of the other vehicles shall then be developed from the base model and the dynamic behaviour simulated and the results compared to the limit values.

Limited tests on the actual modified vehicles must be undertaken to confirm that the modifications have been correctly applied to the model. The tests required will depend on the type of modification being undertaken but may include:

- wheel load and load distribution,
- static tests on the full vehicle,
- slow speed I quasi-static tests,
- laboratory tests of components,
- Iimited on-track tests, for example vehicle body accelerations,

5.4.3 Supplement the range of test conditions

When tests according to UIC Leaflet 518 have been carried out, but the full range of conditions has not been satisfied, then it may be appropriate to use numerical simulation to approve the vehicle.

This situation could arise where:

- sufficient track length is not available to meet the requirements for some zones,
- the full range of speed and cant deficiency has not been tested,
- the range of wheel/rail (contact) conditions has not been covered.

The following conditions must be satisfied by the available test results to allow model validation:

- maximum test speed (service speed + 10 %) has been tested over track of a suitable length and quality to demonstrate stability,
- maximum cant deficiency (I_{adm} + 10 %) has been tested,
- tests have included some very small radius curves and an adequate range of wheel/rail contact conditions,
- track conditions are sufficiently rough to excite the vehicle suspension.

A vehicle model shall be set up and validated by comparison with the available test results in accordance with Appendix K of UIC 518 version 2009.
Numerical simulations shall be undertaken for any test zone where the test results are not complete. It is not permitted to use the same track section for both tests and simulations. The combined track sections from tests and simulations for each test zone must meet the requirements of point 6.1 of UIC 518:2009.

5.4.4 Reporting

The report must include:

- a full validation report in accordance with Appendix K of UIC 518 version 2009 for the original vehicle model;
- description of any modifications to the vehicle and model and how these have been validated, including independent review of the process;
- a full report of the results of the simulations, in accordance with the normal format of test reports described in point 11 -page 51of UIC 518:2009;
- a description of how the issues identified in point 6.5 -page 30 of UIC518:2009 and Appendix J -page 87 of UIC 518:2009 have been included in the simulations

5.5 Test performance and assessment for the acceptance of vehicles dynamic behavior[71]

5.5.1 Test performance and assessment

Before its introduction in commercial service, any new or modified railway vehicle is submitted to the examination of its dynamic behaviour. In Europe, this assessment is usually carried out by submitting the vehicle to a series of on-line tests performed according to one of the following documents:

- UIC Code 518 (latest issue: 4th edition - September 2009),

- EN 14363 (latest issue: December 2005 - currently undergoing full revision).

Both documents will be considered here as equivalent, their discrepancies being the result of different stages of evolution of an identical set of rules. They specify how to perform and assess the dynamic tests, and describe in particular:

- the test conditions to be performed,

- the quantities (forces and/or accelerations at various locations on the vehicle) to be measured,

- the signal filtering and processing rules to be applied, in order to derive the estimated values representing the expected behavior of the vehicle in reference operating conditions,

- the limit values to which these estimated values shall be compared for vehicle acceptance.

A summary of these rules is given hereafter, limited to what is necessary for a correct understanding of the issues addressed in this paper. To make the description as clear as possible, simplifications have been made on some details.

a. Test conditions

According to its nature, design and use, a vehicle may need to be tested empty and loaded, in normal and degraded modes, in one or both running directions. The following conditions apply for every of these vehicle testing configurations.

Test conditions are based on the maximum speed (V_{lim}) and cant deficiency (I_{adm}) expected in service. The useable parts (fulfilling the requirements recalled hereafter) of the test runs have to be classified into 4 test zones defined as:

- zone 1: tangent track - minimum 10 km partitioned into 250 or 500 m track sections,

- zone 2: large radius curves - minimum 5 km partitioned into 100, 250 or 500 m track sections,

[71] http://www.railway-research.org/IMG/pdf/g8_dupont_patrick.pdf

- zone 3: small radius curves (radius 400 m ≤ R ≤ 600 m) - minimum 50 sections of 100 m each,

- zone 4: very small radius curves (250 m ≤ R < 400 m) - minimum 25 sections of 70 m each.

Additional test conditions to be fulfilled on each of the individual track sections making up these test zones are the following:

- on zone 1: test speed shall be V_{lim} + 10% (tolerance +/- 5 km/h),

- on zone 2: test speed shall be between V_{lim} and V_{lim} + 10% (tolerance +/- 5 km/h),

cant deficiency shall be in the range 0,70.Iadm ≤ I ≤ 1,15.I_{adm},

with at least 20% of the track sections above 1,05.I_{adm},

- on zone 3: the mean radius R_m of the track sections used shall be between 450 and 550 m,

cant deficiency shall be in the range 0,70.I_{adm} ≤ I ≤ 1,15.I_{adm},

with at least 20% of the track sections above 1,05.I_{adm},

- on zone 4: the mean radius R_m of the track sections used shall be between 280 and 350 m,

cant deficiency shall be in the range 0,70.I_{adm} ≤ I ≤ 1,15.I_{adm},

with at least 20% of the track sections above 1,05.I_{adm}.

These requirements regarding length and number of track sections, radius, speed and cant deficiency are usually the main conditions taken into account when preparing the test campaign. Their purpose is to explore the parts of the expected operating range assumed to be the most critical:

- Maximum speed of the vehicle (zones 1 and 2), in order to assess the risk of instability (zone 1) and to evaluate track forces and car body accelerations at top speed (mainly zone 2),

- Maximum cant deficiency (zones 2 - 3 - 4), generating high levels of forces (lateral and vertical) on the outer rail and on the track itself,

- Very small radii (zone 4), where lateral forces and wheel climb ratio Y/Q may become critical.

Beside these basic requirements, two aspects are also specified: contact conditions and track quality.

Requirements about wheel/rail contact conditions are now directly expressed in terms of equivalent conicity (Tanγ_e) on test zone 1 (high values to assess the risk of instability and low values to explore low frequency car body motions) and radial steering index (q_E) on test zone 4 (to make sure that the sample includes sections with both easy and difficult curving possibilities, resulting in low and high values of the lateral forces and the Y/Q ratio). Experience in this field remains however limited.

As regards track quality, the current specifications are based on the distributions, among the track sections used for the evaluation, of the standard deviations of longitudinal level (Z_s) and lateral alignment (Y_s) of the track. The requirement is that, on each test zone and separately for each of these two parameters, at least 50% of the track sections have a quality worse than QN_1, including at least 10% with a quality worse than QN_2. QN_1 and QN_2 are defined for various classes of V_{lim} speed.

b. Quantities to be measured

The so-called normal method is based on the measurement of wheel/rail contact forces Y (lateral) and

Q (vertical), of which the following assessment quantities are derived:

- ΣY, total force exerted laterally on the track by a wheel set (track shift force),
- Y/Q ratio, used to assess the risk of derailment by wheel flange climbing,
- Y_{qst}, mean value of lateral curving force exerted on the outer rail in curves,
- Q, maximum vertical force exerted on the outer rail in curves,
- Q_{qst}, mean value of vertical force exerted on the outer rail in curves.

The first two (ΣY and Y/Q) are considered as safety relevant, others are used to assess track fatigue.

In addition, lateral accelerations are measured on the bogie frame (above the wheel sets), and lateral & vertical accelerations are measured in the car body (above bogie pivots). Car body accelerations are used in the normal method to assess running behavior.

Alternative methods, defined as simplified, are described in UIC 518 and EN 14363, mostly based on these (bogie frame and car body) accelerations. But, although the same methods could be applied to accelerations, the present paper only focuses on the influence factors of wheel/rail forces assessed in the frame of the normal method as safety and track fatigue criteria.

c. Signal processing

The process described hereafter shall be repeated for each vehicle configuration (load case, normal or degraded mode, running direction…), test zone (1 to 4), measuring point and assessment quantity.

The first stage of the statistical process determines a representative value of the assessment quantity on each of the N track sections making up a test zone. In a second stage, these N individual values are used to calculate the estimated value of this assessment quantity on this test zone.

For maximum assessment quantities (ΣY, Y/Q and Q), the 99,85% value (and/or the absolute value of the 0,15% value of a negative signal) of the filtered signal on each track section is picked out:

For the whole test zone, when a one-dimensional statistical process is used, the maximum estimated value is defined as mean + 3 standard deviations of the N individual values (2,2 standard deviations only in the case of Q - track fatigue quantity).

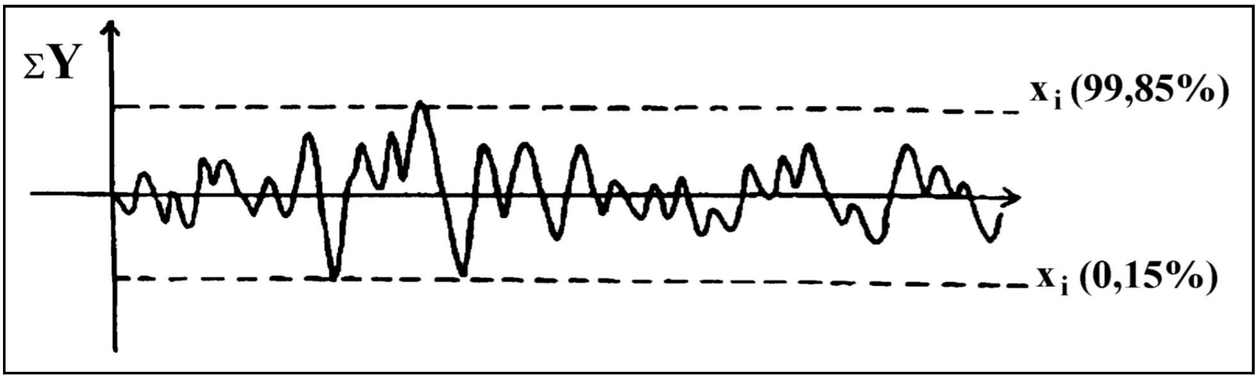

Figure 38 Extraction of 0,15% and 99,85% values on a track section

For quasi static quantities (Y_{qst} and Q_{qst}), the 50% value of the filtered signal on each track section is used and the estimated value on the test zone is defined as the mean of these N individual values.

d. Limit values (axle load ≤ 22,5 tonnes)

The limit values for safety and track fatigue assessment quantities are the following:

$(\Sigma Y)_{lim} = (10 + P_0/3)$ kN P0 being the static axle load in kN

$(Y/Q)_{lim} = 0,8$

$(Y_{qst})_{lim} = 60$ kN(in UIC 518:2009: $30 + 10500/R_m$, with R_m the mean radius of track sections used)

$(Q_{qst})_{lim} = 145$ kN

$(Q)_{lim} = (90 + Q_0)$ kN with limitation according to V_{lim} speed Q_0 being the static wheel load in kN.

5.5.2 Current practice and difficulties

From the summary given above, it is obvious that defining a test programme meeting all the required test conditions is a very hard task. Indeed, on a given network, it is usually possible to find test lines fulfilling either of the requirements stated in UIC 518 or EN 14363. But the difficulty lies in the fact that these requirements shall be fulfilled simultaneously, on a certain number of individual track sections.

The combination of track radius (R), test speed (V) and test cant deficiency (I) is usually achievable on most networks, but the compilation of the minimum number of valid sections for every test zone may require running on various lines, sometimes far from each other (with an impact on test duration and cost). In some countries, legal requirements even make it difficult to perform the over-speed runs requested (which, for some vehicle types, implies to exceed the local top speed of the line).

Requirements on track quality come in addition, with 2 difficulties. The first is that the test programme, as already said, is primarily designed in order to meet the above-mentioned requirements (minimum number N of sections acceptable in terms of R, V and I), the track quality being then taken as it is, be it valid or not (usually not!). The other is that, even when special attention is paid to track quality, it is noted that the track quality distributions requested (50 % sections ≥ QN_1, including 10 % ≥ QN_2) are very demanding, because the QN values are in many cases (especially regarding alignment Y_s) higher (worse track quality) than representative values of most European networks. For both reasons, specifications about track quality are often regarded as not practicable and are merely ignored, whereas track defects are known to have a prominent influence on the dynamic response.

This is obviously one of the fields where the present work could help greatly, until the QN numbers, now under examination, are revised (and, in a second stage, replaced by another method to describe the quality of test tracks).

Beside the non compliance to various test specifications for the reasons quoted above, we shall also consider the requirements which, even when complied with, allow a rather wide range of acceptable test conditions, potentially leading to diverging results as regards the acceptance of a vehicle.

This initially came to evidence for the evaluation of Y_{qst} for locomotives (see 5.5.5 a), where the possible range for the mean radius R_m of track sections on test zone 4 (280 m ≤ R_m ≤ 350 m) lead to a possible spread of 10 kN in the estimated Y_{qs}t. So the same vehicle could be found acceptable (Y_{qst} ≤ 60 kN) if the mean radius of sections in test zone 4 was in the upper part of the allowed range, or unacceptable if this radius was in the lower part of the range.

This observation, that acceptance or rejection of a vehicle could depend on its test conditions rather than on its own capability, led to the proposal by UIC Project Group in charge of the revision of Code 518 of a new expression of the Y_{qst} limit value, now also adopted by European Rolling Stock TSI (Technical Specification for Interoperability): $(Y_{qst})_{lim} = 30 + 10500/R_m$.

CEN TC256 Working Group 10 should transfer this new formulation into the revised EN 14363, although the correction according to R_m should be introduced during the estimation of Y_{qst} rather than into the limit value. Indeed, it looks sensible to keep the limit absolute, related to the resistance of the track which obviously is a matter of components strength and not of curve radius.

5.5.3 Scope and benefits of the present work

According to EN 14363:2005 and UIC 518:2009, it is now compulsory for quasi static quantities and optional for maximum quantities to use a two dimensional statistical procedure. This way, the dynamic behaviour of the vehicle can be assessed in perfectly normalised conditions regarding cant deficiency, which is indeed one of the most influent parameters on various assessment quantities.

UIC work on the lateral force Y_{qst} of locomotives (see 5.5.5.a) showed that it was possible to neutralize the influence of track radius variations, allowing a more absolute assessment of this quantity and more objective comparisons between vehicles, possibly tested in different ranges of curve radii.

The aim of the present work is to investigate whether such normalising procedures could be extended to any assessment quantity, in order to compensate for the variability of all relevant test conditions (including track quality). This variability may be the result of allowances in the assessment procedure (ranges of values being specified rather than single target values) or deviations from this procedure.

The possible use of the methods to be developed could be the following:

- when the value specified for one of the relevant test conditions (radius, speed, cant deficiency, track quality…) was not achieved during a vehicle test, the estimated values of the assessment quantities affected by variations of this parameter could be recalculated for the specified value,
- when the possible range to be achieved for a parameter (radius in the case of Y_{qst}, for example) is so wide (and this parameter so influent) that testing at one or the other end of this range could result in diverging conclusions, the estimated values of the assessment quantities affected by variations of this parameter could be adjusted to a specific value of the parameter (in this range).

The correction should, for the reason stated at the end of point 5.5.2, be applied during the second stage (test zone) of the determination of an estimated value, before comparison with the limit value. It could be applied uniformly to all vehicles, or with variations according to vehicle type or characteristics, or even be based on coefficients derived from a specific study of each vehicle. This question will be developed at the end of this paper.

By allowing the use (after careful recalibration) of test data not strictly complying with specifications, such an approach offers numerous potential benefits:

- economy: avoids scrapping test data (the collection cost of which is always high) and sometimes repeating the test,
- accuracy: provides a tool to estimate the dynamic values in precise test conditions, rather than use the values corresponding to slightly (or even largely…) inadequate conditions,
- confidence: real test data is used as the input, and (probable conclusion) adjusted according to its own statistical evolution rules; this may be safer than using a mix of test and simulation results,
- reduced severity: the correction thus achieved has not the punishing effect of the correction factors proposed by Appendix H.3 of UIC 518:2009 when the number of valid test sections is not sufficient and the values are estimated from a reduced sample, with the same confidence level.

Note: some of these benefits, of course, are exclusive of each other. As an example, in a given case, the first one (economy) shall be considered by honest people (who would ignore improper data) and the second one (accuracy) by less regarding people (who would use such data without correction)!

5.5.4 Principles of the work

Considering the influence of mean radius R_m on the estimated value of Y_{qst}, evidenced by UIC work, CEN TC256 Working Group 10 decided, in the frame of the ongoing revision of EN 14363, to explore the respective influences of variable test conditions on the test results (to start with: ΣY, Y_{qst}, Q, Q_{qst}).

The basis for this work is the performance of multi linear regressions of vehicle test results (output) against test conditions (input), conducted and analysed as explained hereafter.

The aim is to use the results of such regressions in the adjustment of the initial estimated values, when the overall test conditions did not meet the target values of radius, cant deficiency, track quality.

a. Data

The starting point is a table (under EXCEL or another suitable format) of test conditions and results, including the following data (with one line per track section and as many columns as available input parameters or output quantities):

- identification of each test track section: run n°, start km, end km,

- track layout of each section: radius R, cant D, curvature1/R (or 1000/R),

- test running conditions on each section: speed V, cant deficiency I,

- track quality on each section: lateral, vertical (standard deviations), gauge (mean value),

- other available quantities: equivalent conicity Tanγe, radial steering index q_E, friction coefficient…,

- statistical values of the assessment quantities on each track section:

- 99,85 % values for maximum quantities (ΣY, Y/Q, Q),

- 50 % values for quasi static quantities (Y_{qst}, Q_{qst}).

b. Method of analysis

For every assessment quantity under investigation, the analysis uses a multi linear regression tool to determine a regression rule of the following form, using all the available information:

$X = a_0 + \Sigma_{ai}.x_i$ (i = 1, 2… n)

X being the assessment quantity under investigation (99,85 % or 50 % value)

and the x_i being the available input parameters.

This regression rule is associated to various statistical figures describing the relevance of the formula:

- global regression coefficient R^2 (should be as near to 1 as possible),

- standard deviation (in kN) of the part not explained by the regression,

- Student coefficient t_i of each parameter i (same sign as the associated coefficient a_i).

It is usually assumed that there is a significant influence of a parameter when the associated Student t_i is, in absolute value, higher than 2. In other words, a regression rule as expressed above should only be used when all the t_i associated to the parameters used in this expression are greater than 2. However, it immediately appears (after performing the first round of regression) that most Student t_i do not reach this minimum.

So a sensible way to carry on the analysis consists in removing the parameter associated with the lowest t_i (in absolute value) and use the regression tool again. A new formula is obtained, with new coefficients a_i associated to new Student t_i. Usually, at this early stage, very little information is lost: the global R^2 decreased (and standard deviation increased) only marginally, whereas the Student t_i of the remaining (n - 1) parameters improved a little.

The same process is then repeated, after elimination of the remaining parameter associated with the lowest t_i (in absolute value), until all Student t_i are greater than 2 (in absolute value). In favourable cases, about 2 or 3 input parameters remain in the expression, and the global R^2 has not decreased too much since the beginning, because the parameters which have disappeared during the process were either of little influence on the force studied, or closely correlated to the remaining parameters.

Such a formula, using a reduced number of input parameters (statistically independent) associated to high Student t_i and retaining a rather high global R^2, can be used with relevance to estimate the force investigated as a linear combination of the appropriate test conditions.

c. Representation and harmonisation of results

Experience gathered over a long period and from the analysis of numerous tests showed it was necessary to adapt the process described above. Indeed, if from a scientific point of view it looks sensible to leave statistics identify the most appropriate representation of the influences, this usually results in heterogeneous formulae:

- the representations may use inter-correlated influence factors, which is not appropriate because in such a case their real influences interfere (coefficients in the regression may be shifted from one parameter to the other without altering the precision of the regression),

- they may also use irrational parameters, making the physical understanding of the phenomena difficult and the interpretation hazardous,

- the influence factors may vary from one vehicle to another, making comparisons impossible as well as the definition of common correcting rules.

This is why it has been chosen, in the 1st stage of the work, to force in some way the regressions, by seeking expressions of the forces under investigation as linear combinations of:

- 1 parameter representing track layout. Among the possible options (radius, curvature and cant), cant soon disappeared and **curvature 1/R** was finally preferred to radius, as providing a better representation of the increasing forces in sharp radii,

- 1 parameter representing running conditions; speed should be the right option for the behavior on tangent track (not studied here); for curves **cant deficiency I** usually appears to be a better choice (and has already been, for many years, the parameter used in two dimensional analyses),

- 1 parameter representing track quality (for maximum quantities only, as it is physically obvious that quasi static quantities are independent on local defects of the track). It occurred that the **standard deviation of lateral defects Y_S** usually provided better results than vertical Z_S. This is easily understandable for lateral forces (ΣY), obviously more influenced by lateral defects, but regressions carried out on vertical forces Q provided results not significantly better with Z_S than with Y_S. Various explanations may be sought, such as a roll movement due to lateral defects, influencing the balance of vertical forces between both wheels. It shall also be noticed that lateral and vertical quality of the track, when examined using standard deviations over a certain length, are closely correlated together, which makes the use of any parameter (Y_S or Z_S) rather neutral. This is why, in order to allow a more homogeneous representation, Ys has been retained for the analysis of both lateral and vertical forces.

Other parameters, when available, have sometimes provided very good results, adding a relevant plus to the comprehension of the physical phenomena and the validation of what the optimal test conditions should be. Among these, we may first of all quote the friction coefficient µ, unfortunately not directly accessible during tests (and out of control during operation), but which may be roughly approximated by the Y/Q ratio on the inner wheel of the guiding wheel set. Very recent analyses also showed the relevance of the newly defined radial steering index q_E, when analysing lateral forces or the Y/Q ratio in sharp radius curves. Some words will be said at the end of this paper, but lack of data did not allow a systematic use of these additional parameters in the frame of the present work.

So, at this stage, quasi static quantities will be approximated by regression rules of the form:

Y_{qst} or Q_{qst} = a + b/R + c.I

and maximum quantities will be approximated by regression rules of the form:

ΣY or Q = a + b/R + c.I + d.Y_s

5.5.5 First results

a. Locomotives - Study of Y_{qst}

In the frame of the revision of UIC Code 518, the curving force Y_{qst} of locomotives in small and very small radius curves (250 to 600 m) was analysed. The results are summarised in the following tables.

For a first set of locomotives, tested in Italy (4 types, the first of which was tested with new and worn wheel profiles), the $(Y/Q)_i$ ratio on the inner wheel, used to approximate the friction coefficient µ, was available as a mean value over every track section, together with curvature 1/R and cant deficiency I.

The results are really outstanding: as the first table shows, it is clear that these 3 parameters 1/R, I and $(Y/Q)_i$ explain most of the variability of Y_{qst}, R^2 values being all above 0,80.

Student t values for (Y/Q)i are above 20, which shows that the influence of this parameter is even stronger (and constant) than that of curvature (also obvious, with Student t above 10).

Cant deficiency comes only third... although it is currently specified in EN 14363 as the normalizing parameter in a two dimensional evaluation! This could at first be explained by the rather limited range of evolution of I (contrived by imposed test conditions) as compared with the more open range of radii taken into account (250 to 600 m), but additional studies confirmed this trend.

The relative influences of these 3 parameters can be compared using the product of their coefficient in the regression (b, c and d respectively) and the standard deviation of each of these parameters; resulting values are 5 - 6 kN for friction, 3 - 4 kN for curvature and less than 1 kN for cant deficiency.

Locomotive	IT1 new	IT1 worn	IT2	IT3	IT4	Mean
Global R^2	0,84	0,88	0,81	0,87	0,87	0,85
Standard error	3,40	2,76	3,20	3,44	3,30	3,22
Nb sections	252	248	263	266	229	252
a (constant)	-2,84	-7,23	-8,96	-13,31	0,69	-6,33
b (1/R)	9742	7481	5522	9045	6754	7709
c (I)	0,008	0,076	0,063	0,050	0,049	0,049
d $(Y/Q)_i$	56,8	45,5	96,8	94,5	64,2	71,6
Student t_a	-1,28	-4,17	-3,65	-5,76	0,34	-2,91
Student t_b	17,29	14,77	10,98	17,10	11,48	14,32
Student t_c	0,50	5,97	3,60	3,23	3,44	3,35
Student t_d	21,61	23,85	22,67	31,88	22,54	24,51
$\sigma(1/R)$	0,00045	0,00045	0,00046	0,00045	0,00046	0,00045
$\sigma(I)$	15,0	16,0	12,1	15,1	16,7	15,0
$\sigma(Y/Q)_i$	0,088	0,104	0,051	0,073	0,091	0,081
$b.\sigma(1/R)$	4,4	3,3	2,5	4,0	3,1	3,5
$c.\sigma(I)$	0,1	1,2	0,8	0,8	0,8	0,7
$d.\sigma(Y/Q)_i$	5,0	4,7	4,9	6,9	5,9	5,5

Table 8 Locomotives - Expression of $Y_{qst} = a + b/R + c.I + d(Y/Q)_i$

The analysis was extended to 3 locomotives tested in France, but without use of $(Y/Q)_i$; the next table confirms the first results as regards the relative influences of curvature and cant deficiency, the first always being more important than the second. The lack of information when losing $(Y/Q)_i$ is obvious when considering the global R^2 values obtained on the Italian locomotives, now around 0,50.

Locomotive	FR1	FR2	FR3	IT1 new	IT1 worn	IT2	IT3	IT4
Global R^2	0,69	0,59	0,10	0,54	0,59	0,44	0,36	0,56
Standard error	4,06	5,39	8,86	5,75	5,03	5,52	7,59	5,95
Nb sections	94	88	93	252	248	263	266	229
a (constant)	14,80	28,37	20,08	14,69	-0,24	21,62	17,21	2,42
b (1/R)	9649	10227	6157	14203	12975	9968	12055	13204
c (I)	0,186	0,027	0,109	-0,039	0,021	0,061	0,039	0,075
Student t_a	3,48	6,06	2,16	4,20	-0,08	6,11	3,71	0,66
Student t_b	8,29	10,88	1,72	15,99	15,79	12,48	10,50	14,27
Student t_c	4,83	0,91	1,75	-1,46	0,93	2,04	1,14	2,94

Table 9 Locomotives - Expression of $Y_{qst} = a + b/R + c.I$

Considering (after the previous study) that cant deficiency was not so influent, an extended sample of locomotives (including some for which the individual values of cant deficiency were not available) was analysed using only curvature (single regression). The results are shown in the next table.

Locomotive	FR1	FR2	FR3	IT1 new	IT1 worn	IT2	IT3	IT4	DE1	DE2	DE3	SJ1
Global R²	0,61	0,59	0,07	0,53	0,58	0,43	0,35	0,54				
Standard error	4,52	5,38	8,96	5,77	5,03	5,55	7,59	6,05				
Nb sections	94	88	93	252	248	263	266	229				
a (constant)	32,38	32,23	29,79	10,42	2,18	27,88	21,66	11,45	33,00	28,00	48,00	9,71
b (1/R)	12871	10306	8572	13662	13347	10543	12591	14259	9840	12620	6960	12792
Student ta	13,15	16,04	3,96	5,43	1,27	15,72	8,73	5,54				
Student tb	12,11	11,02	2,57	16,88	18,59	14,02	12,03	16,44				

Table 10 Locomotives - Expression of $Y_{qst} = a + b/R$

The evolution of R^2 values between Tables 9 and 10 shows that little information was lost, curvature being much more influent here than cant deficiency. It may also be noticed that the coefficients for 1/R are fairly close to each other, which allowed UIC Study Group in charge of the revision of Code 518 to derive from this study a new expression of the limit value:

$\mathbf{(Y_{qst})_{lim} = 30 + 10500/R_m}$, R_m being the mean radius of test sections.

When Y_{qst} is estimated using a 2-dimensional analysis according to cant deficiency (as requested now in UIC 518 and EN 14363 for all quasi static quantities), this allows a normalisation of test conditions regarding both radius and cant deficiency. However, the present study shows that it would be highly desirable to include also friction in such a normalisation. Work in this field is still ongoing.

It must also be said that this study, based on locomotives only (being the most critical type of vehicle in terms of Y_{qst}), would lead to different coefficients for other types of vehicles (multiple units, freight wagons), as will be shown later in this paper. So the limit value stated above should be considered as a first step towards normalisation, but still to be improved.

b. Extension to other vehicles and quantities

In the frame of CEN WG10, the work carried out on Y_{qst} for locomotives was extended to other assessment quantities (ΣY, Q, Q_{qst}) and other types of vehicles (multiple units and freight wagons). The idea was to investigate whether the rather promising results obtained could be generalised, thus providing a way to normalise test results to target conditions which may be difficult to achieve.

This work was performed using the test results of 7 vehicles tested in France:

- 3 locomotives (1 BB + 2 CC),

- 1 standard design EMU (powered - leading - and non powered bogies),

- 1 articulated DMU (powered - leading - and non powered - Jacobs - bogies),

- 2 freight wagons (fitted with 2 2-axles bogies).

With the exception of the non powered bogies of the EMU and DMU, the investigations were made on the first (leading) wheel set of the vehicle, where the forces are usually the highest. As explained in section 5.5.4.c, the regression rules investigated are of the form:

$\mathbf{Y_{qst}}$ **or** $\mathbf{Q_{qst} = a + b/R + c.I}$ for quasi-static quantities,

$\mathbf{\Sigma Y}$ **or** $\mathbf{Q = a + b/R + c.I + d.Ys}$ for maximum quantities.

The analyses are summarised in tables of results, not reproduced here, but similar to those presented in section 5.a. The main conclusions are given hereafter, for each assessment quantity.

c. Sum of guiding forces $\Sigma Y1$

The regression is rather good on both CC locomotives ($R^2 = 0,69$) and on both bogies (0,64 and 0,58) of the articulated DMU, but much poorer ($0,17 \leq R^2 \leq 0,30$) on the EMU and the freight wagons.

Using the same criteria as in 5.5.1.a (Student t values for the significance of a parameter and product coefficient x standard deviation of this parameter to characterise its influence on $\Sigma Y1$ variations), we can say that there is always a positive correlation of $\Sigma Y1$ with cant deficiency and track defects ($\Sigma Y1$ increases when cant deficiency increases or when track quality deteriorates). The share of both parameters in the variability of $\Sigma Y1$, assessed by coefficient x standard deviation index, is similar (about 2,2 kN each, as an average on the 9 investigated bogies).

As regards curvature, the influence is clearly positive on the vehicles (locomotives and DMU) providing good regressions, but appears to be very uneven on the EMU and wagons. On the former, the coefficient x standard deviation index of 1/R is similar to that of cant deficiency or track quality.

Talking now about the coefficients of the regression (sensitivity of $\Sigma Y1$ to the variations of curvature, cant deficiency and track quality), and considering the locomotives, the orders of magnitude are:

- 5300 kN/(m-1) for curvature variations,

- 0,17 kN/mm for cant deficiency variations,

- 9 kN/mm for track quality variations (measured by standard deviation of lateral alignment).

For the other vehicles the sensitivity of $\Sigma Y1$ to cant deficiency variations is usually around 0,14 kN/mm and its sensitivity to track quality around 4 kN/mm only for multiple units …but 12 kN/mm for wagons! The influence of curvature is too unstable to be quoted.

d. Guiding force Y_{qst1}

The results found on the locomotives (none of which was among those studied in 5.5.5.a) are rather good (global R^2 of at least 0,50) and fully confirm the conclusions of section 5.5.5.a:

- strong and stable influence of curvature:
    - very high Student t values, largely above 10,
    - similar sensitivity coefficients, around 10500 kN/(m-1), consistent with the new limit,
    - σ.coef index around 5 kN,

- secondary influence of cant deficiency:
    - positive but lower Student t values,
    - positive but uneven sensitivity coefficients,
    - σ.coef index around 1 kN.

But the results on the EMU, DMU and wagons are really inconclusive:

- most Student t values are around zero (except some values on multiple units),

- sensitivity coefficients are low and uneven,

- σ.coef indices never reach 2 kN (except for curvature on the trailing bogie of the EMU: 4 kN).

As a conclusion, the analysis and the values reported in section 5.5.5.a are confirmed for locomotives, but cannot be extended to other vehicle types, on which the influence factors of the guiding force Y_{qst}, if any, remain to be determined.

For all vehicle types, the influence of friction, identified on Italian locomotives as being even stronger than the influence of curvature, should be investigated. Other parameters (such as the radial steering index q_E) might also be relevant in the generation of Y_{qst}.

e. Vertical force Q1

Although virtually all correlations are positive (Q increases when curvature, cant deficiency or track defects increase), the results are about the same as for ΣY1: rather good for locomotives and rather uneven for multiple units and freight wagons.

For the 3 most conclusive cases (CC locomotives and leading bogie of the DMU), we find an evenly distributed influence of curvature, cant deficiency and track quality, with Student t values around 7 and σ.coef indices between 1 and 6 kN. The coefficients of 1/R, I and Y_s in the regression, however, differ from a vehicle to another, making it difficult to derive common rules.

An unexpected result of these studies, though not incidental because this is a constant trend, is that Q forces are depending on the curve radius; in fact, when examining together the regressions for both wheel sets of the bogie we find that:

- when curvature increases, the load on the outer wheel of the first wheel set increases, whereas the outer wheel of the second wheel set unloads of a similar quantity; on average, on the 9 bogies investigated, the coefficient is about +/- 4000 kN/(m^{-1}),

- the influence of cant deficiency is rather evenly shared on both wheel sets, with mean coefficients of 0,17 and 0,20 kN/mm respectively,

- the influence of track defects is also rather evenly shared, with coefficients around 7 kN/mm.

As expressed above, these coefficients are only mean values, the individual figures being scattered, with a more stable influence of cant deficiency, then track defects, then curvature, and the regression being more reliable in the case of locomotives as for the other quantities.

f. Vertical quasi-static force Q_{qst1}

The usual conclusions apply: locomotives provide the best regressions, although the leading bogie of the DMU also stands out, and even the freight wagons show some consistency here!

The results are consistent with the analysis of Q1 regarding the positive correlation with curvature (opposite effect on the second wheel set) and cant deficiency, with similar influences.

Note: the UIC study carried out for the extension of the axle load to 25 tonnes had led to the following theoretical formula, validated by test results:

$$\mathbf{Q_{qst} = Q_0.(1 + 2{,}3.h_G.I/e^2)}$$

where: Q_0 = static wheel load in kN

h_G = height of centre of gravity above rails

I = cant deficiency

e = distance between rolling circles (1500 mm / standard gauge)

The accuracy of this formula has been checked on various vehicles, but with the previous definition of Q_{qst} (where all outer wheels of a bogie are combined). In a separate assessment of wheel sets 1 and 2 the influence of curvature (positive on the first wheel, negative on the second) shall be included.

5.5.6 Conclusion - Possible applications and next steps

These studies on the influence factors of Y and Q forces showed differences between vehicle types, locomotives usually providing better results than multiple units and - even more - freight wagons.

In favorable cases, linear regressions of test results allow the estimation of the forces investigated (ΣY, Y_{qst}, Q and Q_{qst}) as linear combinations of curvature 1/R, cant deficiency I and track quality Ys. These regressions open the door to possible recalculations of the estimated values of these quantities for target (specified in EN 14363) values of the relevant test conditions.

In some cases the regression rules may be consistent enough to derive general normalisation rules, which can take the form of:

- a common correction coefficient, which can be used to correct the original estimated value by adding a term coefficient x missing amount of the influencing factor, before comparison with the limit value,

- or a limit curve (such as $\mathbf{30 + 10500/R_m}$), including the most important influencing parameters.

In such a situation, it is not even necessary to perform a specific analysis for the vehicle considered; this is the approach proposed for Y_{qst} on locomotives (but not valid for other types of vehicles).

However, even when the regressions found allow a sensible representation of the vehicle behavior, usually this expression is only applicable to this vehicle, because similar studies on various vehicles lead to too different coefficients. In this case the correction proposed above in order to upgrade the estimated values to target test conditions remains possible, but shall be made using the coefficients (b, c, d…) determined by a specific analysis of this vehicle’s results.

If the regression rule obtained is: $a + b/R + c.I + d.Y_s$

the correction to be applied is: $b.(1/R_t - 1/R_m) + c.(I_t - I_m) + d.(Y_{st} - Y_{sm})$

where index t refers to target conditions (EN 14363) and index m to the mean conditions achieved during the test (or possibly the 90% value when talking of Y_s).

Then, there are cases where no useable regression can be found ($R^2 \approx 0$), which was often the case in the present study for freight wagons for example. In such a situation, no sensible correction can be applied; however, a low R^2 being associated with low regression coefficients, no correction needs to be applied, and it can be assumed that testing in the target conditions would have produced similar estimated values.

The implementation of these principles, the advantages of which have been described in Section 5.5.3, necessitates a confirmation of the first results, exploring:

- the feasibility of the process described (linear regressions of vehicle test results → determination of regression coefficients → correction of the original estimated values),

- the possibility to define, in limited cases, common coefficients,

- the influence of other parameters, some of which look promising (friction, radial steering index).

This is expected to be done in the frame of CEN TC256 WG10, based on the study of more test results from different types of vehicles tested in different countries.

6 Homologation of railway vehicle in India[72]

Newly designed rolling stocks are required to meet certain test Criteria before the design can be introduced in Indian Railways system. RDSO has a Standing Criteria Committee, which deliberates over the criteria to be met by such vehicles, and other issues related to performance of vehicles on rails. The composition of this Committee has been approved by the DG/RDSO as under:

1 ED/Testing - Convener
2 ED/Motive Power
3 ED/Carriage
4 ED/Wagon
5 ED/Electric Loco
6 ED/Track Design
7 ED/Track Machines
8 ED/Research

6.1 Procedure followed by IR - Conditions & Procedure for Oscillation Trails

Detailed trial runs are carried out on the selected test stretches on Up or Down line in increment of speed on a particular set of conditions, called series, as specified in the test scheme up to a maximum speed specified or till such time criteria conditions are not exceeded. The trial conditions for detailed runs normally applicable are:

a) Test speed range with increment of speed

b) Empty and/or loaded

c) Instrumented Bogie Leading and Instrumented Bogie

Trailing, crane leading and match truck leading

d) Wheel profile, i.e., new, worn and wear adopted

e) Air springs inflated and deflated

Detailed trial run is followed by a long confirmatory run over a stretch of about 30 km (10 to 50 km) section or specified in document at the maximum safe speed achieved during detailed trial. During the long confirmatory run, specific observation is made for any

72 Goverment of India, Ministry of Railways“ A technical guide on Oscillation trails“ Report No. MT-334 of April 2002 by Testing Directorate , Research Design and standards organization (RDSO) Lucknow.

resonance tendency on bridges. The basic idea of the long run is to confirm that the values of parameters are in general conformity with the values found in the detailed trial section. This run will cover a few hard spots like level crossings, culverts and bridges as far as possible. Riding of the vehicle over such points (resonance or amplitude build up) is specially mentioned in the trial report.

The first step for oscillation trial is to plan. DT or ED nominates the Unit, which will conduct the oscillation trial. The nominated unit prepares a detailed programme for conducting OT including assistance needed and advises the COM, CE, CME, CEE of the Railway with copies to the concerned DRM and branch officers. Concerned Directorates of RDSO are also advised of the programme, which includes fitness checking of the locomotive or vehicle etc. DT nominates oscillograph Car and staff coaches required for the OT and necessary movement programme is issued.

The Unit studies the test stretches and section where OT is to be conducted. Alternate test stretches are identified from TM Directorate in case of any difficulty for conducting OT, like, speed restrictions, operational problem etc.

The second stage is preparation, which involves discussion with DRM and/or divisional officers regarding OT. Movement of OC with required instrumentation and staff coaches to the stabling station. Movement of locomotive with duly calibrated speedometer and desired wheel profile (new or worn) from shed to originating station. Test vehicle and oscillograph Car are moved to a C&W sick-line for welding of instrumentation brackets etc. Test vehicle is checked by design Directorate especially clearances etc and is certified fit for trial. Instrumentation of test vehicle and formation of test special is carried out and TXR staff does under-gear examination.

In case the test vehicle is a locomotive, then load-cell assembly, specially, spacers or measuring wheel has to be fitted in the diesel shed. Similarly, in case the test vehicle is a wagon, then load-cell assembly, specially, spacers have to be fitted in C&W sick-line. Two Oscillograph Cars may be needed if two trials are being done simultaneously, say for example have loco and coach. Otherwise, only one OC is used.

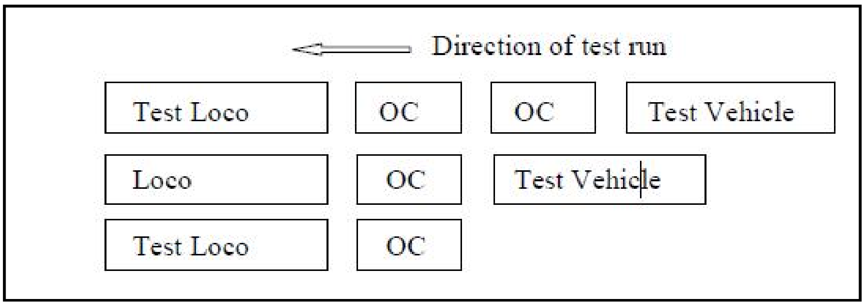

Figure 39 Schematic representation of test train configuration

All signals from transducers after conditioning through signal conditioners are recorded on chart recorder and/or on DAS. ‘LabVIEW’ or ‘DASYlab’ software is used in DAS. Detailed running commentary is made from loco cab regarding kilometer post/stone, speed, facing and trailing points of station yard and hard spots like bridge, culvert, level crossing etc.

Kilometer posts/stones are marked on chart paper through ‘flick’ operated by the commentator in the loco cab and manually written on the chart paper. However, in case of DAS, the above items are recorded through function keys of the keyboard.

The above test data is analysed manually in case of chart recorders and through analysis software programme labVIEW in case of DAS. Analysis is made for nominated 20 curve, straight and station yard in case of detailed run at each speed. However, in case of LCR, maximum values of vertical and lateral accelerations with RI are worked out kilometer wise duly indicating speed and remarks like level crossing, bridge, culvert, facing point, trailing point, speed restriction etc.

A correction factor of 1/R should be used to calculate bogie rotation (in degrees) if measured with LVDT. Displacement of LVDT = bogie rotation(□)*distance of LVDT from bogie pivot (R). During data acquisition, spikes or abnormal peaks are sometimes observed due to extraneous factors like noise, line voltage fluctuation, OHE interference, momentarily loose connection, sparking etc. Even after using on-line low-pass filters; these spikes cannot always be prevented, resulting in erroneous interpretation of the data.

Determination of the 99.85th percentile value is useful to deal with such situations. The 99.85th percentile value is the highest value after discarding 0.15% largest values from the data. A substantial difference between the 99.85th percentile value and the maximum value is indicative of such abnormal peaks in the trace. In such cases, the raw data should again be passed through an off-line software low-pass filter, and processed again. If substantial difference between the maximum and the 99.85th percentile value still persists, the 99.85th percentile value itself should be reported as the maximum value. It may be noted that UIC 518 prescribes treating the 99.85th percentile as the highest value for analysis of all parameters as a matter of course.

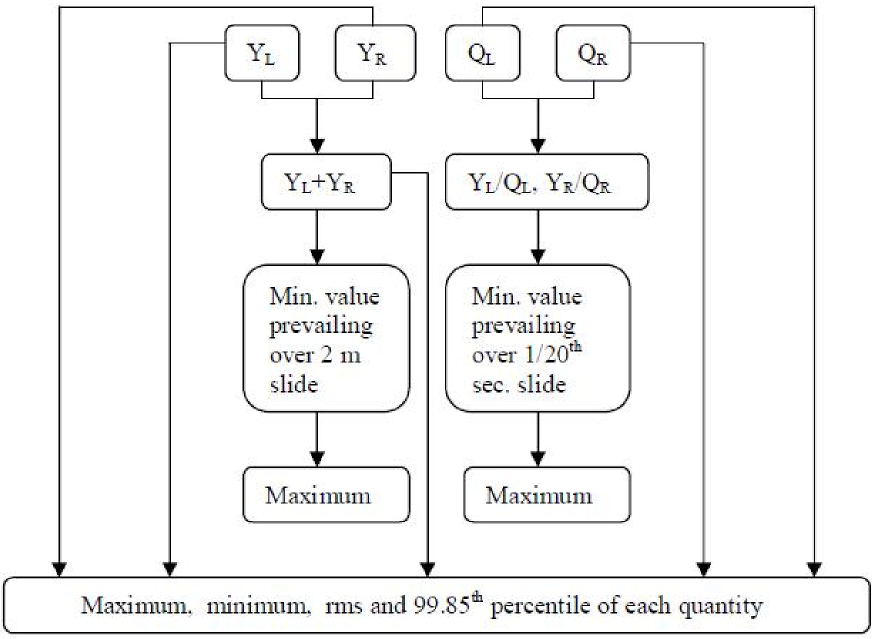

Figure 40 Flow diagram for processing of measuring wheel data

Based on the above data analysis, a draft report is made by the unit. The report is made in a standard format decided by ED and includes chapters as detailed below.

1 Contents

2 Report summary which includes report no, unit no, test objective, file reference, type of stock, nature of trial, test period, sponsoring directorate, design features, test site, test result, cost of trial.

3 Background

4 Objective of trial

5 Design features which includes design features of the stock for which trial is being carried out, salient vehicle parameters, sketch or drawings if necessary.

6 Trial scheme and test procedure: which includes composition of test special, direction of run and recording, track structure comprising rail, sleeper and ballast, trial conditions etc.

7 Parameters recorded: which includes instrumentation done with instrument type and number, type of DAS, filtering, signal conditioner setting, sample rate, type of earthing etc.

8 Assessment criteria

9 Discussion of test results: which includes wedge test, results of detailed run and LCR, resonance tendency on bridge, calculated quantities etc.

10 Conclusion.

Sample oscillographs of vertical and lateral accelerations of detailed sections at maximum speed under various conditions are annexed to the report. The draft report is put up to ED for approval and after approval, the draft report is sent to the Motive Power Directorate, Sponsoring Directorate, Track Design Directorate, Bridges & Structures Directorate and Concerned design Directorates for comments.

The comments from the above Directorates are reviewed and incorporated as necessary in the final report. The raw data (in a Zip drive or a CD-ROM) and a copy of the final report (in a floppy disc) is sent to RMDO for record after organising and converting the raw data files into text or excel files, organising the files into proper folders and sub-folders and giving descriptive filenames and folder names. The final report is given a MT number by RMDO. Copies of the report are sent to Motive Power Directorate – one copy, Track Design Directorate – one copy, Bridges & Structures Directorate – one copy, Sponsoring Directorate – one copy, concerned design Directorate – one copy, RMDO – two copies, Publication cell – two copies and SO/RM – one copy for file.

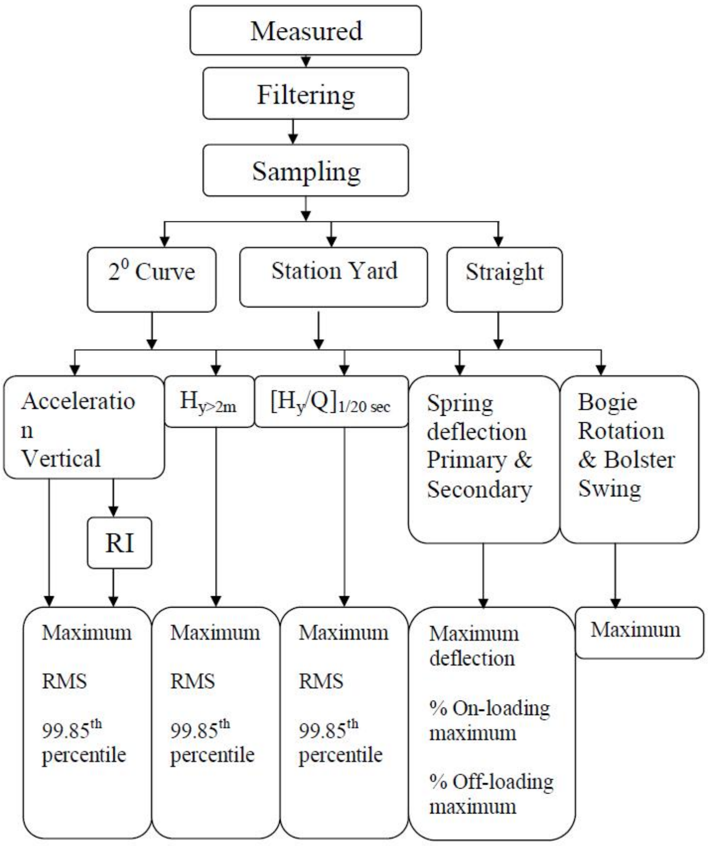

Figure 41 Flow diagram for analysis of oscillation trial data

6.2 Confirmatory Oscillograph Car Run

Confirmatory Oscillograph Car Run' is conducted with instrumented locomotive and/or vehicles, which are proposed to be cleared for speeds above 110 kmph on B.G. and above 75 kmph on M.G. on the entire route at the maximum proposed speed.

Vehicle	Parameter recorded	Measuring equipment	Location of transducer	Filter setting
Loco	Vertical & lateral accelerations	Accelerometer strain gauge type of range +/- 2g	On floor level near to leading bogie pivot	5 Hz
Vehicle	Vertical & lateral accelerations	Accelerometer strain gauge type of range +/- 2g	On floor level near to trailing bogie pivot	5 Hz for coach
Oscillograph Car	Vertical & lateral accelerations	Accelerometer strain gauge type of range +/- 2g	On floor level near to non generator end bogie pivot	5 Hz

Table 11 Oscillograph car run details

6.3 Wedge test for frequencies and damping factor

Wedge test is conducted in order to determine rolling, pitching and bouncing frequencies and damping factor of the locomotive or of the test vehicle under empty and load.

The test is to be carried out on a level and straight main line track with ballast cushion and track structure similar to that of the trial section. No permanent structure or obstructions, i.e., platform, wall, building etc should be present on either side of the track where wedge test is to be done. The test vehicle should be moved only at a rolling speed over the wedge and allowed to drop nearing zero speed from the wedge.

The sponsoring directorate gives the design values. Actual values obtained are reported. The wedge test is carried out during oscillation trial and normally, before commencement of detailed trial runs.

The instrumentation set up for recording vertical and lateral accelerations of the test vehicle is used for this test. No separate set up is needed. The vertical or lateral acceleration is recorded according to the test condition as detailed below.

Measurement	Position of wedge	Channel recorded
Bouncing	Wedges placed under all wheels & loco or vehicle made to ride over the wedges simultaneously & drop	Vertical
Pitching	Wedges placed under wheels of instrumented bogie & loco or vehicle made to ride over the wedges simultaneously & drop	Vertical
Rolling	Wedges placed under wheels on one side only & loco or vehicle made to ride over the wedges simultaneously & drop	Lateral

Table 12 Test conditions

The wedges are placed on rail table as detailed at wedge test schematic diagram and loco or vehicle is made to ride over the wedges and drop simultaneously. It is, thus, necessary that all wedges should be kept at uniform distance from wheel.

The traces of accelerations are analysed manually in case of chart recorders or through computer software programme in case of DAS.

If x1 and x2 are the amplitudes of accelerations in bouncing mode of two consecutive oscillations after the drop from wedge, then,

Damping factor, $D = d/[39.44+d^2]^{0.5}$

Where,

$d = [\log_e (x1/x2)]$ and frequency, $(f) = 1/T$ or 100/(no of samples)

for 100 samples/second rate of data acquisition.

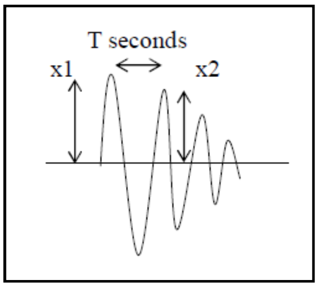

Figure 42 Amplitude of accelerations

Based on the above data analysis, the values of frequencies in three modes and damping factor are reported under the heading wedge test.

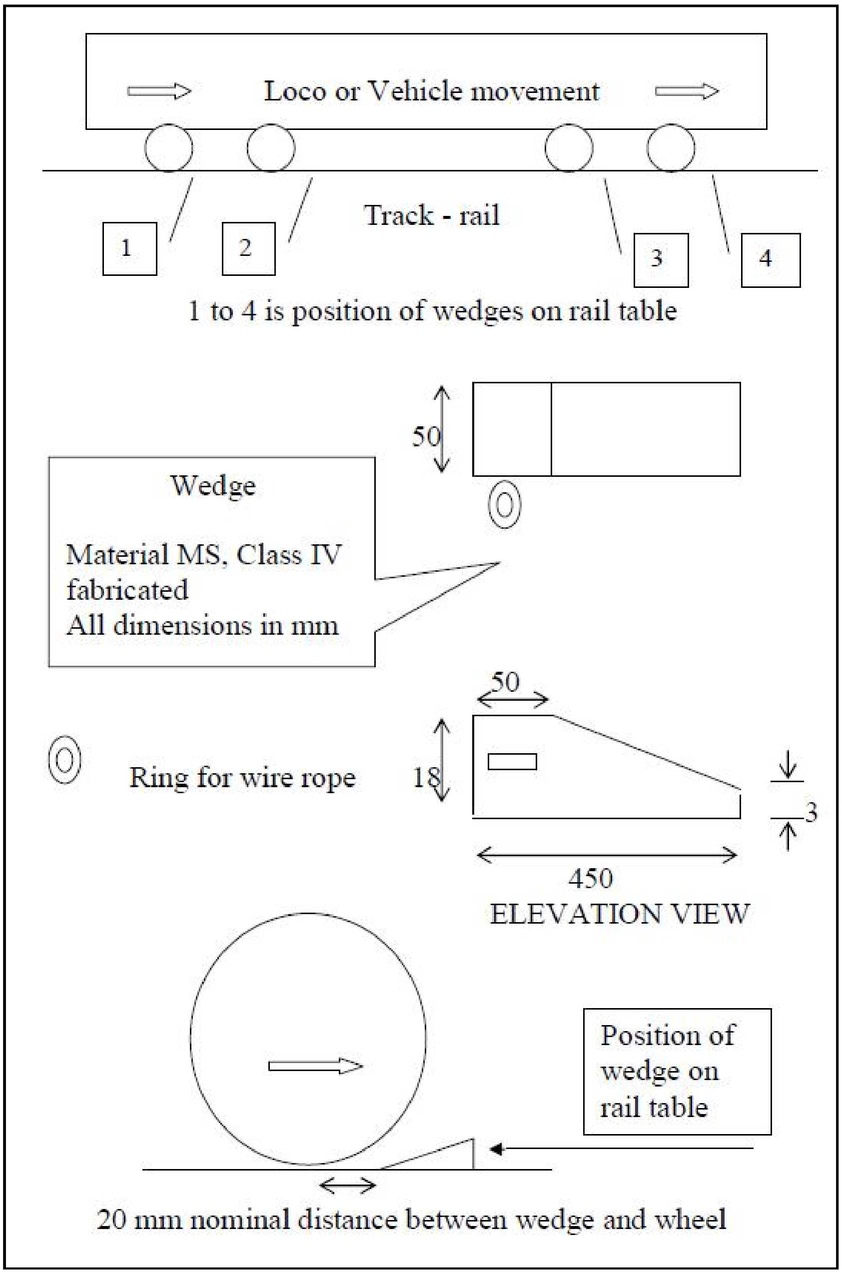

Figure 43 Wedge test schematic diagram

6.4 Quality of Ride

Human sensation of comfort is dependent on displacement, acceleration and the rate of change of acceleration. In other words, the product of displacement, acceleration and the rate of change of acceleration could be used as a measure of discomfort during travel.

For sinusoidal vibration with β as the amplitude and ω as its periodicity, the formula, developed by Dr. Sperling, hence known as Sperling's Ride Index, can be derived as under:

Displacement: $s = \beta * \sin \omega t$

Velocity: $v = ds/dt = \beta * \omega * \cos\omega t$

Acceleration: $a = dv/dt = -\beta * \omega^2 * \sin \omega t$

Impulse: $I = da/dt = -\beta * \omega^3 * \cos \omega t$

Thus, level of discomfort $\alpha\ a * I * s$

Taking the maximum value of parameters over the half wave of displacement,

The level of discomfort $\alpha \quad (-\beta\omega^2)*(-\beta\omega^3)*(\beta)$

or, $\alpha \quad \beta^3\omega^5$

Defining the RI as a measure of discomfort,

RI $\alpha\ \beta 3\omega 5$

or, $RI = k* \beta 3 * \omega 5$ –––––– (1)

If 'b' is the amplitude of acceleration, then, $b = -\beta * \omega 2$ and also, $\omega = 2\pi f$ where, f is the frequency of vibration. Substituting β and ω in equation (1) above,

$$
\begin{aligned}
RI &= k * (-b/\omega^2)^3 * \omega^5 \\
&= -k * b^3 / \omega \\
&= K * b^3 / f
\end{aligned}
$$

For an individual, the sensation of vibration varies according to an exponential law and thus,

$RI = 0.896 * (b^3 / f)^{0.1}$ --------- (2) (for ride quality)

In order to take human reactions, the formula is modified taking into a correction factor and thus,

$RI = 0.896 * [b^3 * \phi(f) / f]^{0.1}$ -------- (3) (for ride comfort)

Where ϕ (f) is a frequency dependent factor expressing human vibration sensitivity and is different for vertical and lateral vibration components.

The term Ride quality means that the vehicle itself is to be judged. Ride comfort means that the vehicle is to be assessed according to the effect of mechanical vibrations on people in the vehicle.

The w_z factor for ride quality is $0.896*(b^3/f)^{0.1}$ and for ride comfort is $0.896*[b^3* \phi (f)/f]^{0.1}$. The term ride comfort is equivalent to RI for locomotive and coaching stock and ride quality is equivalent to RI for freight stock.

The following classification of RI with reference to subjective appreciation is usually adopted on Sperling's scale as per ORE report no. 8 of C-116:

Ride quality

Ride Index	Appreciation
1	very good
2	good
3	satisfactory
4	accepted for running
4.5	not accepted for running
5	dangerous

Ride comfort

Ride Index	Appreciation
1	just noticeable
2	clearly noticeable
2.5	more pronounced but not unpleasant
3	strong, irregular but still tolerable
3.25	very irregular
3.5	extremely irregular, unpleasant, annoying, prolonged exposure intolerable
4	extremely unpleasant, prolonged exposure harmful

In the analogue or chart recorder method, the correction factor for frequencies below 0.5 Hz are not relevant since the average common frequency is always above 0.5 Hz. In DAS method, since the frequency of every half wave has to be considered individually, some of the half waves may have frequencies less than 0.5 Hz for which a correction factor of 0 has been assigned. This is because frequencies below 0.5 Hz have very low energy levels and do not affect the ride comfort.

The accelerometers are placed on the floor level of the vehicle near the center pivot for measuring the acceleration and calculating RI.

The correction factors for various frequency values are as under:

Vertical mode

0 for f < 0.5 Hz

0.325 f^2 for 0.5 < f < 5.4 Hz

$400/f^2$ for 5.4 < f < 20 Hz

1 for f > 20 Hz

Lateral mode

0 for f < 0.5 Hz

0.8 f^2 for 0.5 < f < 5.4 Hz

$650/f^2$ for 5.4 < f < 20 Hz

1 for f > 20 Hz

The traditional RDSO method for calculation of RI by taking a common average frequency for all the half waves and average amplitude for each range of peaks (called Bin method) was essentially adopted from old SNCF (French Railway) practice as mentioned in ORE report no. 8 of C116 of 1977. This is an analogue method involving reading of acceleration oscillogram recorded on chart recorder and counting of peaks. The number of peaks is put in the Table 1 for calculation of Σ n and Σ n x. The calculation sheet is valid for calibration of 1 cm = 0.2g, 0.4g etc. Suitable calculation sheet for different calibration may be prepared accordingly.

From the Table 1, f = Σ n / 2t and RI is calculated.

Acceleration range 'g'	Mean Acceleration = b (cm/sec^2)	x= $b^3 * 10^{-6}$	No. of peaks = n	nx
0.00-0.04	19.52	0.008		
0.04-0.08	58.86	0.204		
0.08-0.12	98.10	0.944		
0.12-0.16	137.34	2.59		
0.16-0.20	176.58	5.506		
0.20-0.24	215.82	10.05		
0.24-0.28	255.06	16.59		
0.28-0.32	294.30	25.49		
0.32-0.36	333.54	37.10		
0.36-0.40	372.53	51.80		
0.40-0.44	412.02	69.945		
0.44-0.48	451.26	91.893		
0.48-0.52	490.50	118.01		
0.52-0.56	529.74	148.658		
			Σn	Σnx

Table 13 Ride index calculation

For Locomotive and Coach, by substituting, $\phi(f) = 0.325f^2$ for vertical acceleration and $0.8f^2$ for lateral acceleration in equation (3), we get,

RI Vertical = $2.96 * [\Sigma nx / t]^{0.1}$

RI Lateral = 3.25 *[Σnx / t] $^{0.1}$

For wagon, equation (2) for ride quality or ϕ (f) = 1 is used and we get, RI for both vertical and lateral acceleration,

RI = 3.56 *[Σ nx * / f Σ n] $^{0.1}$

The new method for RI adopted for calculation in computerized DAS is an improvement over analogue method. Instead of calculating RI based on a single common frequency of the oscillogram in the analogue method, RI in DAS method is computed based on the individual frequency of each sine wave. A complete half wave is counted only from one change of sign of the sample value to the next change. This means that a positive half wave has to be followed by a negative half wave and vice versa and incomplete half waves at the two ends of the trace are ignored. Frequency of each half wave is calculated as 's/2n', where, 's' is the sampling rate per second and 'n' is the number of samples starting from the first positive value up to the last positive or zero value for a positive half wave and from first negative value up to the last negative or zero value for a negative half wave. The amplitude for a half wave is the highest positive or negative sample value recorded for that half wave in cm/sec^2.

Average RI = 0.896 *[S {b_i^3 * F (f_i)/ f_i } / n }] $^{0.1}$ -------- (4)

Where,

n = number of completed half waves

i = 1 to n

b_i = peak value of amplitude for the i^{th} half wave

f_i = frequency of the i^{th} half wave

ϕ (f_i) = correction factor for the i^{th} half wave

Sperling's original RI formula is based on the effect of a pure sinusoidal acceleration on human body. In the two methods described above, the half waves have been assumed to be sinusoidal, whereas they are really of irregular, random shape. Para 2.1 of ORE C-116 describes a method of calculating RI, which accounts for the fact that accelerations measured on the vehicle body has not only one single frequency but also a whole spectrum in which the natural frequencies typical of the vehicle are very much pronounced. The evaluation therefore requires that the measured acceleration be resolved spectrally. The wz ride factor is therefore determined for each individual frequency component according to equation wz = [b^3 * B^3] $^{0.1}$ and total ride factor is calculated as w_{total} = [w_{Z1} ^{10} + w_{Z2} ^{10} +… + w_{Zn} ^{10}] $^{0.1}$.

In this method for determining the RI, first a Fast Fourier Transform (FFT) of the digitally acquired data is obtained. The underlying principle behind the analysis is that the effect of a random signal is the same as the sum of the effects of its sinusoidal components.

The theorem states that any periodic or aperiodic signal can be mathematically represented as the sum of a series of sinusoidal signals. For a digitally acquired signal in the form of a time series, the independent continuous time variable is replaced by the discrete sampling period variable 'n'. It can be mathematically shown that for a signal with a total number of N samples, there will be N number of sinusoidal components, each of which is described by the expression for the k^{th} wave.

$(R_k^2 + m_k^2)^{0.5} * \cos [2\pi kn/N + \tan^{-1} (m_k/R_k)]$

Where R_k and m_k are the real and imaginary components of the k^{th} wave represented in vector form. If the data consists of N samples, the FFT consists of N complex coefficients of the form $R_k + im_k$, where k is the coefficient number from 0 to N. Each of these coefficients represents a sine wave with amplitude equal to $(R_k^2 + m_k^2)^{0.5}$, a frequency equal to ks/N, where s is the sampling rate and phase angle equal to $\tan^{-1} (m_k/R_k)$. The remaining method is similar to RDSO's computerised method. Ride index of the k^{th} wave is $0.896 [b_k^3 * \phi(f) /f_k]^{0.1}$.

The data acquired through DAS, say, vertical acceleration for one km stretch is pasted in a column 'A' on an MS-Excel file. Use Excel 'tool' command and select 'Data Analysis' followed by 'Fourier analysis' and 'Input range'. The number of samples should be in the order of 2^n, i.e., 2, 4, 8, 16, 32, 64, 128 … 4096, etc. If required, add zero sample values to make the sample size to 2n. Select 'Output range' option; e.g., 'new worksheet' and FFT analysis is obtained in the format detailed below.

Row No.	FFT analysis	b	f	ϕ	$\Phi(f)$	$[(981xb)^3/f]x\ \Phi(f) = y$
1	DC component		0	180		
2	R+im					
3	R+im					
N/2	R+im					
N/2+1	R+im		50	180		
N/2+2	R-im					
N/2+3	R-im					
N	R-im					
						Σy

Table 14 FFT Analysis Format

Amplitude b = imabs(A1)/N,

Frequency f = [row() - 1] x 100/N and

Phase angle ϕ = imargument(A1) x 180 / PI()

Ride index = $0.896*[\Sigma y]^{0.1}$

Low magnitude of DC value indicates a balanced signal. It is seen that a+ib values of sample no. 2 to N/2 are mirror images of sample no N/2+2 to N having sample no N/2+1 as midpoint. This is due to positive and negative waveform of the sinusoidal wave. It is also seen that FFT analysis is presented in ascending order of frequency components starting with zero frequency for sample no. 1 to 50 Hz for sample no. N/2+1. This is due to the fact that f = ks/N = (N/2) x (100/N) = 50 Hz, i.e., f_{max} = s/2 and sampling rate used for data acquisition is 100 Hz or 100 samples/second.

By calculating $\Phi(f)$ for corresponding frequency, RI is calculated as $0.896x[\Sigma y]^{0.1}$. The RI calculated by this method has generally been found to be 5-25% less than that by RDSO's method; the closer the shapes of the half waves to sinusoidal form, the less being the difference. This method was adopted for calculation of RI for oscillation trials of the LHB coaches on C&M-1 Vol. 1 category track.

Using the FFT technique Bar charts can be drawn e.g., amplitude vs. frequency, phase angle vs. frequency etc. Detailed analysis can be made regarding predominant frequency components, resonance frequency, phase shift between two channels of acceleration etc. Efficacy of hardware filter can also be checked using this technique.

6.5 Certification of maximum permissible speeds for rolling stock as per Policy Circular No. 6

Vide Railway Board's letter No. 92/CEDO/SR/4/0 Pt. dated 23.12.1999 issued by Member Engineering, it was advised that the revised Policy Circular No.6 should henceforth be adopted for all future certification of maximum permissible speeds for rolling stock. This circular was issued under compendium of instructions on rules for opening of railway, permissible speeds, ODC movements and schedule of dimensions (Engineering Standing Order No.13 - Master Correction Slip No. 17/13/1). This circular defines and lays down the procedure for certification of maximum permissible speed for rolling stock.

1 Authority for sanctioning speed of rolling stock

The Railway Board is the safety controlling authority for the Indian Railways and it is the final authority for regulating and sanctioning speeds of all rolling stocks under the Indian Railways Act. The responsibility for determining and certifying the maximum permissible speed for rolling stock has, however, been delegated by the Railway Board and clarifications on this subject issued from time to time. This directive is applicable to all rolling stock other than pre-IRS stock and supersedes all previous instructions on the subject.

2 Sanctioning speed of new designs of rolling stock

2.1 Determination of provisional speed by RDSO

2.1.1 The provisional maximum permissible speed for new design of rolling stock will be determined on the basis of design features and data, and where appropriate, also, on a comparison of the performance of similar designs of stock already in service.

2.1.2 The provisional speed will normally be lower than the designed or projected service speed of the stock and shall not be more than the following:

80 km/h for BG passenger stock;

65 km/h for BG goods stock,

60 km/h for MG passenger stock,

45 km/h for MG goods stock,

35 km/h for NG stock

2.1.3 However, in respect of such stock whose suspension characteristics are similar to and whose axle loads and track loading densities are not exceeding those of the stock already proved in service, the following maximum limits may be followed, with the concurrence of the Chief Commissioner of Railway Safety.

105 km/h for BG passenger stock,

75 km/h for BG goods stock,

75 km/h for MG passenger stock,

50 km/h for MG goods stock,

40 km/h for NG stock.

2.1.4 The provisional speed shall be determined and certified by the Executive Director Standards (Motive Power) in consultation with the Executive Director Standards (Track), Executive Director (Bridges & Structures) and other concerned directorates.

2.1.5 The validity of provisional speed certificate will be five years, except when it is superseded by final maximum permissible speed certificate issued as per para 2.2.

2.2 Determination of final maximum permissible speed by RDSO for new designs

2.2.1 The final maximum permissible speed of all new designs of rolling stock will be determined and certified by the Executive Director Standards (Motive Power) in consultation with the Executive Director Standards (Civil) (Track) and Executive Director (Bridges & Structures) and other concerned directorates.

2.2.2 The final maximum permissible speed of new designs of rolling stock will be determined after due consideration of the services to be performed, on a comparison with similar stock already in service and on the basis of detailed oscillation trials for assessing the riding quality and/or stability. However, for such stock whose suspension and other relevant characteristics such as axle loads, track loading density, etc. are not basically different from those of the existing ones, the detailed oscillation trials may be dispensed with, with the concurrence of the Chief Commissioner of Railway Safety. In case of difference of opinion, the matter will be referred to the Railway Board for final orders.

2.2.3 The detailed oscillation trials will be conducted by the Executive Director Research (Testing) in consultation with Executive Director Standards (Motive Power), Executive Director standards (Track) (Civil) and Executive Director (Bridges & Structures) and the Head of the Mechanical Design Directorate concerned who will evaluate the data.

The final evaluation of detailed oscillation trials data will be made by the Executive Director Standards (Motive Power), in consultation with Executive Standards (Civil) (Track) and Executive Director (Bridges & Structures), who will order re-trials if necessary and suggest modifications. In the evaluation of the detailed oscillation trials for riding stability he will be guided generally by the extant recommendations of the Standing Criteria Committee.

2.2.4 The Commissioner of Railway Safety shall be kept advised of the programme for detailed oscillation trials, so that he may witness the tests if he so desires.

2.2.5 If, for operation at the final maximum permissible speed, any improved standard of maintenance to rolling stock, track, bridges, signaling, OHE, etc. is called for, the same shall be mentioned in the speed certificate issued by the Executive Director Standards (Motive Power).

2.2.6 Stipulations in the speed certificate shall be about standard design/structure of track and bridges. If the conditions obtaining on a section are different, the maximum speed, which can be permitted over such stretch shall be proposed by the Railway in consultation with RDSO if so considered necessary. The Railways will furnish to the Commissioner of Railway Safety details of calculations for the purpose, if and when, such details are called for by the Commission.

2.2.7 CRS sanction for trials shall be valid for one year, after which it will have to be got re-validated by the Railway.

2.3 Multiple operation of motive power units

The speed certificates, both provisional and final, issued by Executive Director Standards (Motive Power) for new designs of motive power units shall invariably indicate whether such units may be used in multiple operation and, if so, the maximum number of units that may be coupled together as well as the special conditions, if any, to be satisfied in regard to track and bridges before permitting such operation.

2.4 Application for sanction by zonal railways

2.4.1 The provisional/final maximum permissible speed certified by the Research Designs & Standards Organisation is merely a recommendation in regard to the maximum speed at which rolling stock can be permitted to be run on specified track structure under average/stipulated maintenance conditions and bridges built to certain specified standards of construction and satisfactory maintenance and is intended to assist the Railway Administration in deciding on the speed at which the rolling stock may be permitted to run on their system for the maintenance conditions actually obtaining.

The Railway shall, on the basis of the provisional/final maximum permissible speed certificate issued by the Research Designs & Standards Organisation apply for sanction to the Railway Board through the Commissioner of Railway Safety, for the running of the stock in terms of the “Rules for opening of Railway or Section of a Railway for Public Carriage of Passengers”. A copy of the detailed oscillation trials report shall be sent to Commissioner of Railway Safety along with the application, Performa for the track, bridge and joint safety certificate are indicated in Annexure A, B, and C respectively. The joint safety certificate to be issued for all rolling stock by the Chief Engineer, Chief Mechanical Engineer, Chief Operations Manager, and Chief Signal & Telecommunication Engineer (Chief Electrical Engineer also in electrified territories) is a positive act of certification in regard to the actual state of maintenance of track, bridges, rolling stock and OHE being adequate for the speed indicated, and is a statutory obligation. In the case of electrical rolling stock and also for other stock in electrified territories, the safety certificate referred to above shall also be signed by the Chief Electrical Engineer. If the speed of the electrical rolling stock to be run/introduced is more than the existing maximum speed of any electrical rolling stock on the section, a certificate as at Annexure-D shall also be furnished by the Chief Electrical Engineer. The officers signing the certificate are required to decide, on the basis of their personal knowledge and experience of the maintenance conditions of the track and bridges, locomotives or other rolling stock, with due regard to relevant information available and the maintenance requirements of the new type of rolling stock, as to whether the operation of the particular type of locomotive or rolling stock on the relevant section of the Railway is safe and practicable with the facilities available on the Railway system.

2.4.2 In the above mentioned safety certificate, it shall clearly be indicated that the speed certified does not exceed the limits laid down by the Research Design & Standards Organisation. In addition, the maximum number of motive power units proposed to be coupled together for multiple operation shall be specifically mentioned with due regard to the strength of track structures and bridges, particularly from consideration of longitudinal loading forces on bridges.

2.5 Recommendation by the commissioner of railway safety

Under Section 6 of the Indian Railways Act'1989, the commissioner of Railway Safety shall scrutinise all relevant documents received from the Zonal Railway Administration with particular reference to ensuring safety and, if he so desires, he shall inspect and try out the rolling stock. The Commissioner of Railway Safety shall then make a proper recommendation to the Railway Board through the Chief Commissioner of Railway Safety for according sanction to new types of rolling stock. A Performa for this purpose is shown in annexure 'E' of the document of IR "A technical guide on Oscillation trails".

2.6 Movement of newly designed rolling stock

2.6.1 The maximum permissible speed for the limited purpose of moving newly designed rolling stock from the manufacturer's works/docks to destination or to the testing point or from the destination/testing point back to manufacturer's works shall be determined and certified by Executive Director (Motive Power) in consultation with Executive Director Standards (Civil) (Track) and Executive Director (Bridges and Structures) and other concerned directorates. The speed for this purpose shall not be higher than the provisional speed mentioned in Para 2.1.2. The maximum permissible speed prescribed by the Research Designs & Standards Organisation will be subject to approval by the Chief Engineer, Chief Mechanical Engineer and Chief Electrical Engineer in case of electrical and other rolling stock on electrified sections of the Zonal Railways concerned, who will ensure that the track and bridges and OHE in the sections concerned are suitable for the new stock at the speed permitted. In such cases no formal approval of the Commissioner of Railway Safety is essential. However, in case it becomes necessary to move the vehicle attached to a passenger carrying train, the sanction of the Commissioner of Railway Safety shall be taken.

2.6.2 If, however, a new rolling stock infringes the schedule of maximum moving dimensions or axle loads are more than that permitted on the section, the condonation of the Railway Board for infringements and of Commissioner of Railway Safety for higher axle loads shall be obtained.

2.6.3 Single movement of any other rolling stock, not covered by Para 2.6.1, may be permitted by the Commissioner of Railway Safety under approved special instructions on obtaining safety certificates from the Railway.

3 Sanctioning speed for tests on new rolling stock

3.1 For carrying out tests on new rolling stock where speeds in excess of the provisional/final maximum permissible speed will be attained, the Executive Director Standards (Motive Power) will determine and certify in consultation with Executive Director Standards (Civil) (Track) and Executive Director (Bridges & Structures) the increments of test speeds from the provisional/final maximum permissible speed and also the maximum test speed, on the basis of the design features and data and other information furnished by the Head of the Mechanical Design Directorate concerned, along with the particulars of track and bridges. The Zonal Railway Administration shall obtain the permission of the Commissioner of Railway Safety for conducting the tests on their system on a test section to be indicated by Executive Director Standards (Motive Power), after submitting a joint safety certificate duly signed by the Chief Engineer, Chief Mechanical Engineer, Chief Operating Manager and Chief Signal & Telecommunication Engineer (and also by the Chief Electrical Engineer in case of electrical and other rolling stock on electrified sections.)The test stretches in the test section shall be advised by Executive Director Standards (Track Machines & Monitoring).

3.2 Details of tests such as condition of test vehicle and criteria of test track including track tolerances, vehicle parameters to be measured and their limiting values, required test speed, etc. will be laid down by RDSO's Standing Criteria Committee.

4 Reducing the speed of existing rolling stock and restoring the same

4.1 In the event of adverse reports on riding characteristics of stock already certified or on its adverse effects on track or bridges, the Zonal Railway Administration shall immediately impose a speed restriction under advice to RDSO and Commissioner of Railway Safety. The Executive Director Standards (Motive Power) in consultation with Executive Director Standards (Civil) (Track), Executive Director (Bridges & Structures) and the concerned Executive Directors will further reduce the speed, if considered necessary for safe operation, pending further investigations. The lifting of the speed restriction and determining of the final maximum permissible speed will be made by the Executive Director Standards (Motive Power) on the basis of investigations which may include detailed oscillation trials on the stock as existing and as modified to improve its riding stability characteristics. Executive Director Standards (Motive Power) shall then certify the final maximum permissible speed in consultation with the Executive Director Standards (Track), Executive Director (Bridges & Structures) and the other concerned directorates.

4.2 Whenever the Commissioner of Railway Safety considers that the maximum permissible speed of a stock already certified requires restriction on any section or sections of the railway, he should immediately instruct the Railway Administration to impose the speed restriction and report the matter in detail to the Chief Commissioner of Railway Safety. The Railway shall promptly act on the Commissioner of Railway Safety's instructions, pending review.

4.3 The Zonal Railway Administration shall seek the approval of the Commissioner of Railway Safety in accordance with the procedure mentioned in Para 2.4.1 and 2.4.2 for restoring the prescribed maximum permissible speed after giving effect to such modifications as may be specified. The imposition of speed restriction and its restoration shall in all cases be intimated to the Railway Board.

4.4 The Commissioner of Railway Safety shall scrutinise all relevant documents received from the Zonal Railway Administration, and if he desires, he shall inspect and try out the rolling stock before conveying his approval for restoration of the prescribed maximum permissible speed with necessary modifications as may have been specified.

5 Increasing the speed of existing rolling stock by making improvements

5.1 Where trial fittings are introduced on existing stock or on stock obtained on a repeat order, with the prime objective of improving the riding characteristics, both at existing speeds and/or higher speeds, the maximum permissible provisional speed of the stock concerned shall be decided by the Executive Director Standards (Motive Power) in consultation with Executive Director Standards (Track), Executive Director (Bridges & Structures) and other directorates concerned. The Executive Director Standards (Motive Power) will determine and certify in consultation with Executive Director Standards (Track), and Executive Director (Bridges & Structures) and the Head of the Electrical and other concerned directorates in respect of electrical rolling stock, the final maximum permissible speed on the basis of investigations, which may include detailed oscillation trials. For these trials, necessary sanction shall be obtained by the railways from the Commissioner of Railway Safety in accordance with the procedure mentioned in Para3.

5.2 The procedure to be followed for obtaining the sanction of the Railway Board by the Zonal Railways through the Commissioner of Railway Safety shall be in accordance with

Para 2.4.1, 2.4.2 and 2.5.

6 Increase sanction of speed of nominated trains on specific routs

Before permitting regular operation of trains at speed above 105 kmph on the BG and above 75 kmph on the MG, the following procedure shall normally be followed, unless otherwise decided with the concurrence of the Chief Commissioner of Railway Safety:

6.1(a) For sevice speed 105 km/h and up to 110 km/h on BG

For permitting speeds above 105 km/h and up to 110 km/h on B.G. with a particular type of rolling stock, the Zonal Railway shall conduct route proving runs using portable accelerometers mounted on the rolling stock (locomotives and vehicles which are proposed to be cleared for speeds from 105 to 110 Km/h) for recording vertical and transverse accelerations throughout the route. If the results obtained satisfy the stipulated criteria as given in Appendix-1, Railway shall approach the Commissioner of Railway Safety for permitting operations up to 110 Km/h on B.G. However, route proving run by the use of portable accelerometers, as stated above, for speeds above 105 Km/h and up to 110 Km/h on B.G. is not necessary on the sections where such type of rolling stock is already plying with the same speed on other nominated trains. Train-wise sanction for operation up to 110 Km/h is not required to be obtained from CRS if the Railways certify to CRS that they would strictly follow all the conditions and stipulations laid down by him in the case of first nominated train at 110 Km/h on that route including the load of the train.

(b) For speed above 110 km/h on B.G. and above 75 km/h on M.G.

Having established the speed potential of stock up to the maximum proposed speed by carrying out detailed oscillation trials on selected test stretches earlier, it would be necessary to conduct confirmatory oscillograph car runs with instrumented locomotive and/or vehicles which are proposed to be cleared for speeds higher than 110 Km/h on B.G. and 75 Km/h on M.G, on the entire route at the maximum proposed speed. For these tests, necessary sanction shall be obtained in accordance with the procedure mentioned in Para 3. These tests are required even in case of stock for which detailed oscillation trials have been dispensed with, with the concurrence of the Chief Commissioner for Railway Safety.

6.2 However, route proving runs/confirmatory oscillograph car runs before permitting a speed above 105 Km/h on B.G are not necessary on the sections where such type of rolling stock is already plying at the same or higher speed on other nominated trains of the same composition. Zonal Railways while approaching the CRS for introduction of such trains shall furnish detailed information on all the relevant safety aspects concerning various disciplines involved.

6.3 The adequacy of the brake power available on the locomotive in conjunction with the coaching stock to be used in the proposed train, vis-à-vis the signaling system available on the route, will have to be established by the Zonal Railway (for speeds above 105 Km/h and up to 110 Km/h on B.G. and up to 75 Km/h on M.G.) and by RDSO (for speeds above 110 Km/h on BG and above 75 Km/h on M.G.)

6.4 The joint safety certificate required to be submitted to Commissioner of Railway Safety for this purpose should be signed by the Chief Engineer, Chief Mechanical Engineer, Chief Operating Manager and Chief Signal & Telecommunication Engineer, and Chief Electrical Engineer also in electrified territories and in respect of electrical rolling stock.

7 Imposition of temporary and permanent speed restrictions by the zonal railways administration.

The above instructions do not apply to temporary and permanent speed restrictions, which the Zonal Railway Administration may consider necessary to impose on either rolling stock, or on certain stretches of track, or on bridges, on account of sub-standard conditions or for any other reason.

8 Sanction for the use of rolling stock already running on any sections (S) of a Railway

In the case of rolling stock already running on any section(s) of a Railway, the sanction can be accorded by the Commissioner of Railway Safety on the submission of safety certificates as per Annexure A, B and C. A Performa for sanction is given in Annexure F of the document of IR “A technical guide on Oscillation trails”.

9 Special trails and conditions of operation

Sometimes trains have to be run under special conditions, which are not encountered, in normal operation. Many a time trials may be required to establish the feasibility of such operation. Such operation and trials would be governed by the stipulations given in Appendix 2 of the document of IR “A technical guide on Oscillation trails”..

10 Maximum speed for trails

The maximum speed for different type of trials shall be as under:

Detailed oscillation trials: 10% excess of the final maximum permissible speed, except on curves where it will be governed by the provisions of Permanent Way Manual. Route proving Runs: Same as the maximum permissible speed for the train.

Emergency Braking Distance, Rating and performance, Coupler force and Signal Interference trials: same as the maximum permissible speed for the train. The speed mentioned above will have a tolerance of + 5 km/h and-2km/h.

11 New rolling stock

A new rolling stock in the context of this Circular would mean a stock having different principal dimensions, a different bogie design, new designs of braking system, and/or suspension details like axle load, track loading density, unsprung mass being different. Minor change of equipment design and change of internal/equipment layout on the rolling stock would not constitute a new rolling stock unless such changes are likely to significantly affect weight distribution, center of gravity and riding behaviour of the rolling stock. Decision in this regard shall be taken by the Head of the concerned Mechanical directorate in consultation with Executive Director Standards (Track), Executive Director (Bridges & Structures) and Executive Director Standards (Motive Power). In taking such a decision, the Head of the concerned Mechanical Directorate will be guided by the criteria laid down for this purpose by RDSO’s Standing Criteria Committee. In case of any difference of opinion, the matter shall be referred to chief Commissioner of Railway Safety/Railway Board for final orders.

The Railways and the Production Units shall not make major changes in the equipment design and layout on the existing design of rolling stock, already cleared for operation. Such changes, if any, should be made with prior approval of RDSO.

12 Application to the commissioner of railways safety

Application to the Commissioner of Railway Safety for sanction/recommendation shall be sent, as far as possible, at least one month in advance by the Railway Administration.

As per Appendices 1 to 2 and Annexure A to F of the document of IR “A technical guide on Oscillation trails”.

6.6 Third Report of the Standing Criteria Committee

Newly designed rolling stocks are required to meet certain test Criteria before the design can be introduced in Indian Railways system. . RDSO has a Standing Criteria Committee, which deliberates over the criteria to be met by such vehicles, and other issues related to performance of vehicles on rails.

1.0 Necessity of oscillation trails

1.1 Oscillation trials are conducted with the following in view:

(i) To establish that the vehicle is safe to run at a desired speed

(ii) To check the stability of vehicle at that speed

(iii) To check Oscillation behaviour of the vehicle, and

(iv) To check the riding comfort of the vehicle as applicable

1.2 Railway Board's Policy Circular No. 6 lays down the circumstances under which it is mandatory to conduct Oscillation trials.

2.0 Selection of test track

2.1 Oscillation trials shall be conducted over a section containing the following:

(i) A Tangent (straight) track - of about 1 km length. Efforts shall be made to conduct trials over two such stretches.

(ii) A Station Yard having facing/trailing points, and

(iii) A curved track having about 2º curve of length about 700-800m.

2.2 Indian Railways track is classified in two categories:

Main line track - fit for operation less than 110 kmph, and High Speed (C&M-1 Volume-I) track- permitting operation up to 140 kmph.

2.3 Since main line standard track permits speeds less than 110 kmph, in case the test vehicle is designed to run at speeds110 kmph and beyond, its Oscillation trials become necessary on High-Speed track also.

2.4 A vehicle suspension should be so designed that it should be able to run freely on all Indian Railways tracks (in certain cases, it may become necessary to place a restriction in running of vehicle on some track structures due to various reasons). Since Oscillation trials cannot be conducted all over the Railway system, the section chosen for detailed

Oscillation trials should be a representative run down section. The section should generally be such that 90% of Indian Railways track should be better than this section the philosophy being that if a vehicle manages to run satisfactorily on this track stretch, it will be able to run satisfactorily anywhere else on Indian Railways.

2.5 At present, the track geometry parameters are 'peak based' and not Standard Deviation based. The parameters of the selected track should not be worse than the following:

Parameter	**Main Line**	**C&M-1 Vol.-I**
Unevenness	C	B
Twist	C or D	C
Gauge	C	A or B
Alignment	C	C

Table 15 Track parameters

2.6 After detailed oscillation trials have been completed and the safe speed thereby determined, a Long Confirmatory Run should be conducted in each of the configurations mentioned in Para 7. The basic idea of the ‘long run’ is to confirm that the values of parameters are in general conformity with the values found in the detailed trial section. This run will:

(a) Cover a long distance (say, 10-50 km) at the maximum speed determined by oscillation trials of the configuration

(b) Cover a few hard spots like level crossings, culverts and bridges as far as possible. Riding of the vehicle over such points (resonance or amplitude build up) will be specially mentioned in the trial report.

3.0 Test speed

3.1 The vehicle must meet the criteria requirements at a speed, which is 10% higher than its proposed operational maximum speed. For instance, if a vehicle is designed to run at 110- kmph maximum speed, it must meet the criteria when tested at 121 kmph (say, 120 kmph, rounded off to the nearest 5 kmph).

4.0 Instrumentation of prototype vehicle

4.1 The vehicle shall be instrumented to read/record the following parameters:

(a) Acclerations: shall be measured on the vehicle floor as close as possible to the bogie pivot. Acceleration levels shall be measured in both vertical and lateral directions.

(b) Verticle forces: shall be assessed using spring deflections, which shall be measured using Linear Variable Displacement Transducers (LVDT).

(c) Lateral forces: shall be measured at axle box level using load cells.

(d) Bogie rotation, bolster swing: or any other parameter as requested by the designer shall be measured using appropriate instrumentation.

5.0 Measured quantities

5.1 As a part of the Oscillation trials, the following quantities shall be measured:

(i) Body level vertical Accelerations

(ii) Body level lateral Accelerations

(iii) Primary suspension spring deflections

(iv) Secondary suspension spring deflections

(v) Lateral forces

(vi) Bolster swing, as applicable

(vii) Bogie rotation, as applicable

5.2 Bolster swing, bogie rotation and other parameters are of interest to designer, and their effect gets manifested in acceleration and force values. To the extent, separate criteria limits need not be laid down for bogie rotation, bolster swing etc.

5.3 A separate note is being placed as Annexure ‘B’ of the document of IR “A technical guide on Oscillation trails”. detailing the instrumentation and filtration requirements for measurement of different parameters.

6.0 Calculated quantities

6.1 These include:

In locomotives: Ride index, Derailment coefficient, H_{Y2m}

In Carriages: Ride Index,

In wagons: Derailment coefficient, H_{Y2m}, Ride Index

(where assessment of forces is not possible)

(Ride Index shall be taken as Sperling Ride Index)

7.0 Calculated quantities

7.1 Usually, trials shall be done in the following configurations:

A Locomotives: Instrumented bogie leading, instrumented bogie trailing, both above configurations with original wheel profile (IRS thick profile or wear adapted profile) and condemning wheel profile.

B Carriages: in empty and loaded conditions using wear adapted profile

C Wagons: in empty and loaded conditions using wear adapted profile

D Other rolling stock: as required by the designer

7.2 Unless otherwise required by the designer, the free end bogie of Carriages and Wagons will be instrumented. The prototype will thus be the last vehicle in the formation of test special.

7 Comparative results

7.1 Comparative assessment of UIC 518 and IR criteria

Subject	UIC- 518	IR Criteria
Purpose	Acceptance of railway vehicle by conducting dynamic behaviour tests in connection with Safety Track fatigue Quality of ride	Same as UIC-518
Test Speed	= 1.1 x V_{lim}	Upto 1.1 x V_{lim} From provisional speed (of about 60 kmph) In increment of 5 or 10 kmph Long run at safe speed from 10 to 50 km
Test run	>25 km total >10 km on straight >10 km on large radius curve > 600 m >5 km on small radius curve from 250 to 600 m	Detailed run: Straight 1 km min or 2 km. One Station yard (~2 km) One 2° Curve of 700- 800 m length. Long confirmatory runfor 10 to 50 km to validate the results of detailed run and to cover hard spots, bridge (for resonance) etc.
Rail	Dry	Not specified
Loading condition	Coach & wagon- empty & loaded to gross designed Suburban coach- empty & loaded extraordinarily	Same as UIC-518
Position of test vehicle	In rear with loose coupling. Loco on traction hauling. Vehicle in fixed formation according to its position in train-set (EMU/DMU).	Same as UIC-518
Instrumented bogie	In most unfavorable condition, leading or trailing to be determined. Loco - both IBL & IBT	Trailing bogie (free end) Same as UIC-518
Wheel profile	New or Naturally worn in service	Loco & Crane- new & worn Other stocks– wear adapted
Direction of run	If possible, both	In one direction Except loco (IBL & IBT) & crane (crane leading & crane trailing)
Weather	To be recorded in the report	Same as UIC-518

Track category	Standard deviation based in speed range	Main line track for speed less than 110 kmph. High-speed (C&M1 Vol.1) track up to 140 kmph. If test vehicle designed to operate > 110 kmph, trial necessary on high speed track.
Test stretch	50%>QN1, 40%=QN1 -QN2 and 10%=QN2 -QN3QN1– regularly planned MaintenanceQN2– short term maintenanceQN3 = 1.3*QN2Standard deviation based Peak values defined for QN1, QN2 and QN3	Run down track –“90% of IR track is better than this”. Parameter M/ L HS Unevenness C B Twist C/D C Gauge C A/B Alignment C C Based on number of peaks Magnitude of peak not defined Unevenness-A: 0 to 6, B: >6 to 10, C: >10 to 15, D: >15 mm on 3.6m chord Twist- A: 0 to 5, B: >5 to 7.5, C: >7.5 to 10, D: >10 mm on 3.6m base Gauge- A: +3, B: > +3 to +6, C: > +6 mm Alignment- A: < 3, B:> 3 to < 5, C: > 5 mm versine on 7.2m chord. 10 peaks exceeding limit in a category allowed in one km and changed to next higher category if peaks exceeding limit are more than 10.
Criteria applied	Normal or Simplified Normal for ‘new technology vehicle’ Simplified – with Full or Partial procedure on conventional vehicles. Loco (with 2-axle) speed <120 kmph–acceleration body & bogie and speed >120 kmph– H & acceleration body. Loco (with 3-axle) – H & acceleration body Coach - acceleration body & bogie. EMU/DMU – bogie >10t & speed >120 kmph - H & acceleration body, otherwise, acceleration body & bogie. Wagon- acceleration body & acceleration bogie or axle (for non bogie wagon) Special vehicles - acceleration body & bogie or axle (for non bogie wagon)	Full procedure Loco– H & acceleration body Coach– acceleration body Wagon– H or acceleration body Departmental stock– acceleration body

Process	Statistical processing Max estimated value = mean + k*sd, where, k= 3.0 for safety, 2.2 for track fatigue & ride quality and 0 for quasi static quantities.	Maximum value Oscillogram studied for resonance, isolated values etc. % On-loading & offloading
Sampling frequency	200 Hz	100 Hz
Filter acquisition	DAS – low-pass 40 Hz Analogue – low-pass 10 Hz except Q & vertical acceleration body with low-pass of 20 Hz.	LVDT & Load-cell – no filter Acceleration – low pass 5 Hz for loco & coach and 10 Hz for wagon
Filter processing	Y, H, Q & Y/Q – 20 Hz Acceleration lateral bogie – 10 Hz Quasi-static Y, Q & acceleration lateral body – 20 Hz Acceleration body – band-pass 0.4– 10 Hz for ride quality and band- pass 0.4–4 Hz for safety assess- ment RMS quantities – f + 2 Hz, where, f is instability frequency.	High-pass 0.4 Hz
Evaluation norm	99.85th and 0.15th percentile values except for quasi-static quantities 50th percentile for quasistatic quantities (for Curves) Sliding rms is calculated	Maximum value for all quantities

Safety criteria	$\Sigma Y_{lim} = \alpha(10+P/3)$ kN max on 2m where a = 1.0 for loco & carriage and 0.85 for wagon $H_{lim} = \beta *(10+P/3)$ kN on 2m where β = 0.9 for loco & carriage, 0.80 for wagon loaded & 0.75 for wagon empty and 0.9 for special vehicle Acceleration vertical on body max = 4.0 m/s^2 for loco & carriage (single suspension), 3.0 for double suspension and 5.0 for wagon $\ddot{y}^*_{lim}$ = 3.0 m/s^2 (4.0 for wagon 4-wheeler, if $P<60$kN, 4.43-P/140 if $60<P<200$kN or 3.0 if $P>200$kN) $\ddot{y}^+_{lim}$ = 12-M/5 m/s^2 where M is bogie weight in tonnes. Y/Q is 0.8 max for curve radius > 250m <u>Instability:</u> rms $\Sigma Y_{lim} = \Sigma Y_{lim}/2$ <u>OR</u> rms $H_{lim} = H_{lim}/2$ except for 4-wheeler & special wagon (rms $\ddot{y}_{lim}$ = 5.0 m/s^2) <u>OR</u> rms $\ddot{y}^+_{lim} = \ddot{y}^+_{lim} / 2$	Not measured H_{lim}=0.85*(1+P/3) tonnes on 2m for loco, wagon and dept stock. If not measured, max RI of 4.5 is criteria. H/Q<1.0 for 1/20 second for loco, wagon and dept stock. If not measured, max RI of 4.5 is criteria. %Off-loading<100 (understood)
Track fatigue criteria	For Q max = 112.5 kN, Q_{lim} = 90+Q or <200 kN for speed <160 kmph, < 190 kN for 160 <V<200 kmph Quasi-static Y_{lim}<60 kN on curve Quasi-static Q_{lim}<145 kN on curve	%On-loading<100 (understood)
Quality of Ride criteria	$\ddot{y}^*_{lim}$ = 2.5 m/s^2 for loco & carriage and 3.0 for wagon (4.0 for 4-wheeler & special vehicle). Acceleration vertical body max 2.5 m/s^2 for loco & carriage and 5.0 for wagon & special vehicle. RMS $\ddot{y}^*_{lim}$ = 0.5 m/s^2 for loco & carriage (normal), 0.75 for carriage (deflated air spring) and 1.3 for wagon (1.5 for 4- wheeler & special vehicle). RMS acceleration vertical body max 1.0 m/s^2 for loco, 0.75 for carriage (normal), 1.0 for carriage (deflated air spring) and 2.0 for wagon & special vehicle. On curves, quasi-static acceleration lateral body max 1.5 m/s^2 for loco & carriage and 1.3 for wagon.	0.3g (isolated 0.35g) for loco & carriage and 0.55g (isolated 0.6g) for dept stock Same as above Sperling's Ride Index 4.0 for loco & suburban stock, 3.5 for carriage and 4.5 for wagon & dept stock Same as above No quasi-static criteria

Table 16 Comparative assessment of UIC 518 and IR criteria

7.2 Salient difference between OMS and DAS

Sr. No.	OMS	DAS
	Oscillation Measurement System	Data Acquisition System
	Used by Zonal Railways	Used by Testing Directorate
1	Measures: Vertical & Lateral accelerations	Measures: all riding parameters of vehicle
2	No trace / oscillogram of above measurements: provides limited information	Trace / oscillogram available for detailed analysis
	Printed Output in specific format: no of peaks in a range	Computerised Output (.xls format): detailed analysis feasible.
3	Values of peaks not known except for maximum peak	All values of oscillogram are available
4	99.85th percentile, rms values etc cannot be calculated	All values can be calculated
5	Event marker cannot correlate with amplitude	Can correlate, i.e., acceleration values at culvert, bridge, level crossing etc.
6	Sampling rate fixed: 256 count for 1g	Variable: 100-300 samples/second
7	Speed, entered manually, is used for calculating RI.	RI calculated on sampling rate & no of samples (time duration)
8	Calculation of Ride Index is incorrect due to: a) Speed factor b) Average value of acceleration of the range multiplied by no of peaks c) No base shift on curves	Correct & Accurate method: time duration/ no of samples, actual values of acceleration
9	Low-pass Filter hardware 5 Hz	Low-pass Filter hardware 5 /10 Hz and Band-pass filter software 0.4 - 5/10 Hz
10	10 V or 110 V DC	230 V AC

Table 17 Salient difference between OMS and DAS

8 Conclusion

Engineering tests and trials make an important contribution to ensuring the safe, reliable and economical use of the technical systems deployed in today's railway systems. The high complexity of modern railways demands the system wide examination of the interplay of individual components within the entire integrated railway system.

Oscillation trial is conducted on a new or modified design of rolling stock, which is proposed to be cleared for running on IR track. The purpose of oscillation trial is, thus, an acceptance of a railway vehicle by conducting dynamic behaviour tests in connection with safety, track fatigue and quality of ride.

'Policy Circular No.6' issued vide ME/Railway Board letter No. 92/CEDO/SR/4/0 Pt. dated 23.12.1999 (refer chapter XIV) and Third criteria report of 'Standing Criteria Committee' issued in January'2000 and amendment no. RM2/MCI/21 dated 10.07.2000 (refer chapter XV) are the two reference documents based on which an oscillation trial is conducted.

An oscillation trial can be commenced only after receipt of CRS sanction. CRS sanction is accompanied by Joint Safety Certificate from the Railway and Speed Certificate issued by RDSO. In addition, documents like, 'List of curves and bridges', 'Permanent and temporary speed restrictions' on the route from the railway applicable on the day of run, 'Test scheme' from the sponsoring/design directorate and latest summarised 'TRC results' for selected detailed test stretches are needed to conduct the trials.

The 'test scheme' includes objective of trial, background of trial, various trial conditions, measurements and parameters to be recorded, design particulars of the test vehicle, load vs. deflection charts for individual and nested springs, necessary drawings of bogie, axle box etc for load-cell fitment, instrumentation etc.

The oscillation trial is carried out either on 'Main line' for operation at less than 110 kmph on 52 kg rail or on 90R rail track and/or on 'High-speed line' for operation at 110 kmph or above and up to 140 kmph on track maintained to C&M1-Vol.1 standard. The criteria for assessment is detailed in the 'Third report of standing criteria committee' issued in January'2000 and amended on 10.07.2000.

8.1 Criteria & Limits at IR

The criteria used during oscillation trial are vertical and lateral accelerations and their ride index, lateral force at axle box level applicable over 2m distance and derailment coefficient. As per 'Third Report of Standing Criteria Committee' issued in January'2000 and amended on 10.07.2000, the limits laid down for different criteria are given in table below.

Locomotives – diesel and electric			
Acceleration	RI	[Hy]>2m*	[Hy/Q]1/20 sec*
		*Minimum values prevailing over the given slide length/ duration	
Maximum value is 0.3g. Isolated value up to 0.35g permitted if no resonant tendency in the region of peak value.	Maximum value is 4.0 and 3.75 preferred. RI method applicable when lateral forces cannot be measured.	Maximum value = 0.85*[1+P/3] where P is axle load in tonnes. Isolated peaks above the limit permissible provided stabilising characteristics of loco noticed subsequent to the disturbance.	Maximum value is 1.0
Coaching stock			
Maximum value is 0.3g. Isolated value up to 0.35g permitted if no resonant tendency in the region of peak value.	Maximum value is 3.5 and 3.25 preferred. For EMU and DMU type of stock, maximum value is 4.0	Nil	Nil
Wagon – freight stock			
Nil	Maximum value is 4.5 and 4.25 preferred. RI method applicable when lateral forces cannot be measured.	Maximum value = 0.85*[1+P/3] where P is axle load in tonnes. Isolated peaks above the limit permissible provided stabilising characteristics of loco noticed subsequent to the disturbance.	Maximum value is 1.0
Departmental stock including crane			
Maximum value 0.55g. Isolated value up to 0.60g permitted if no resonant tendency in the region of peak value.	Maximum value is 4.5 and 4.25 preferred. RI method applicable when lateral forces cannot be measured.	Maximum value = 0.85*[1+P/3] where P is axle load in tonnes. Isolated peaks above the limit permissible provided stabilising characteristics of loco noticed subsequent to the disturbance.	Maximum value is 1.0

Table 18 Criteria and limits by Indian railways

The vertical and lateral acceleration values referred above are to be recorded at a location as near as possible to the bogie pivot. In addition to the above limits, a general indication of stable running characteristics of the loco or vehicle should be seen as evidenced by the movement of the bogie on a straight and curved track and by the acceleration readings and instantaneous wheel load variation and/or spring deflection.

8.2 Standards used by Europe & India for approval of rolling stock.

Standards used in Europe for homologation	Standards used in India for homologation
UIC 518 4th Edition Sept.2009	Report No. MT- 334, April'2002 **A technical guide on Oscillation Trials** The testing Directorate Research design and standard organisation Lucknow, India
EN 14363 01.06.2005	
TSI CR RST - LOC & PAS, 20.04.2011	

Table 19 Standards used in Europe & India

8.3 Criteria for assessment of stability/ riding of rolling stock on Indian Railways

1 Diesel electric locomotives

(i) The lateral/ transverse forces lasting more than 2 meters shall not exceed 0.85(1+P/3) tonnes where P is the axle load in tonnes.

(ii) Isolated peak values exceeding the above limit are permissible provided the record shows a stabilizing characteristic of the locomotive subsequent to the disturbances.

(iii) A simultaneous assessment of the lateral force exerted by the adjacent axles at a point where a particular axle exerts a high lateral force.

(iv) A derailment coefficient should be worked out in the form of ratio between the lateral force (Hy) and the wheel load (Q) continuously over a period of 1/20th second; the value Hy/Q shall not exceed 1.

(v) The value of acceleration recorded at a location, as near as possible to the bogie pivot shall be limited to 0.3 g both in vertical and lateral directions. The peak value up to 0.35g may be permitted, if the records do not indicate a resonant tendency in the regions of peak value.

(vi) A general indication of the stable running characteristics of the locomotive as evidenced by the movement for the bogie on straight and curved track, and by the acceleration readings and instantaneous wheel lead variation.

(vii) In the case of such locos where measurement of forces is not possible, evaluation shall be in terms of ride index which shall not be greater than 4; a value of 3.75 is preferred.

2 Carriage

(i) Ride index shall not be greater than 3.5; a value of 3.25 is preferred. For EMU and DMU type of stock, ride index shall not be greater than 4.00.

(ii) The values of acceleration recorded, as near as possible to the bogie pivot shall be limited to 0.3g both in vertical and lateral directions. A peak value up to 0.35g may be permitted, if the records do not indicate a resonant tendency in the region of the peak value.

(iii) A general indication of stable running characteristics of the carriage as evidenced by the movement of the bogie on a straight and curved track, and by the acceleration readings and instantaneous wheel load variations/spring deflections.

3 Wagons

(i) The lateral/transverse forces lasting more than 2 meters shall not exceed 0.85 (1+P/3) tonnes, where P is the axle load in tonnes.

(ii) Isolated peak values exceeding the above limit are permissible provided the record shows a stabilizing characteristic of the wagon subsequent to the disturbances.

(iii) A simultaneous assessment of the lateral force exerted by the adjacent axles at a point where a high lateral force is exerted by a particular axle.

(iv) A derailment coefficient should be worked out in the form of ratio between the lateral force (Hy) and the wheel load (Q) continuously over a period of 1/20th second; the value Hy/Q shall not exceed 1.

(v) A general indication of stable running characteristics of the wagon as evidenced by the movement of the bogie on straight and curved track, and by the acceleration readings

and instantaneous wheel load variations/spring defections.

(vi) In the case of such wagons where measurement of forces is not possible, evaluation shall be in terms of ride index which shall not be greater than 4.5; limit of 4.25 is preferred.

4 Locomotives, coaching stock and wagons assessment by comparative criteria.

(i) In the event of any difficulty being experienced in the appreciation of the results as per the criteria laid down above for the evaluation of stability for the various categories of stock, or the designer desiring such a test to be carried out, the following comparative criteria shall be made use of:

(ii) The stability of a vehicle is adjudged along with a comparator vehicle of a similar type up to a speed at which the comparator is already in service with satisfactory record of stability.

(iii) For speeds higher than the maximum permissible speed of the comparator, the stability of the new design may be considered acceptable up to a speed at which the riding characteristics continue to be of an order similar to that of the comparator vehicle at its maximum permissible speed.

5 Breakdown crane and departmental vehicles such as OHE inspection cars, spurt car, Track tamping machines.

(i) A lateral force lasting more than 2 meters should not exceed the Prud Homme's limit of 0.85 (1+P/3) tonnes, where P is the axle load in tonnes.

(ii) Isolated peak values exceeding the above limit are permissible provided the record shows stabilizing characteristics of the vehicle subsequent to the disturbances.

(iii) A derailment coefficient should be worked out in the form of ratio between the lateral force (Hy) and the wheel load (Q) continuously over a period of 1/20th second, the values Hy/Q shall be exceed 1.

(iv) The values of acceleration recorded in the cab at location as near as possible to the bogie pivot (as near as possible to axle in case of 4 wheelers) shall be limited to 0.55g both in vertical and lateral directions.

(v) The peak values up to 0.6g may be permitted, if the records do not indicate a resonant tendency in the region of peak value.

(vi) In the case of such vehicles where measurement of forces is not possible, evaluation shall be in terms of ride index, based on the accelerations measured as detailed in Para 6.4 above which shall not be greater than 4.5, but a limit of 4.25 is preferred.

(vii) A general indication of stable running characteristics of the vehicle as evidenced by the movements of the bogie on straight and curved track and lateral force and derailment coefficient or accelerations as the case may be.

6 Criteria clearance of a route for a rolling stock for speeds of 110 kmph and above.

(i) The average number of peaks of vertical and lateral accelerations exceeding 0.30g should be limited to 0.25 peaks/km. However, the number of peaks in any one kilometer should not exceed 1 and where this value is exceeded, the track shall need attention.

(ii) At locations where the peaks of lateral and vertical accelerations exceed 0.35g, the track will have to be attended to.

7 Oscillograph cars (for trails purpose only up to the speed of 180km/h)

(i) Ride Index shall not be greater than 3.75, a few values of 4.0 can be allowed for trial purposes only.

(ii) Accelerations shall not be greater than 0.30g. However, isolated peak values up to 0.45g can be permitted if the records do not indicate a resonant/build up tendency in the region of the peak values.

8.4 Areas of concern in the present method.

The present criteria suffer from the following drawbacks:

1 The system is peak based. This implies that the vehicle suspension is declared unsuitable if one (or a very few) acceleration peak goes above the criteria limits. The presence of thousands of satisfactory acceleration readings thus gets ignored, and the decision gets based on the existence of isolated high peaks.

2 The test track quality is not clearly defined, in the sense that a few bad points in the track tend to affect the judgment of vehicle suspension. Present categorisation of track has certain constraints. Upper limit of the 'last' categorisation of parameters, magnitude and the number of peaks need better definition.

3 The present data acquisition/analysis method is largely based on analogue recording of data on strip chart recorders. This system needs to be changed over to computerised data acquisition and analysis system, which will improve the speed and quality of analysis of data.

4 At present, instrumentation for measurement of forces at rail-wheel contact point does not exist in Indian Railways.

8.5 Future direction for IR

The line of action for IR may be classified in 'Short Term' and 'Long Term' as under:

Short term:

Take a view on the following:

(i) Laying down the range of the test track parameters wherever not precisely defined at present.

(ii) How to deal with isolated peaks encountered during oscillation trials?

(iii) If some limits for acceleration in wagon stock need to be laid down.

(iv) How is a brake van to be treated – as a wagon, coaching stock or departmental stock?

(v) New and worn condition of vehicles.

(vi) Switching over to standard deviation based parameters for test track.

(vii) Switching over to 'simplified method' of UIC-518.

Long term:

Switch over to UIC-518 type criteria.

1. Oscillation trials in USA involve the use of test track specific perturbations deliberately incorporated in it. On the other hand, the UIC method involves use of running lines for field trials. The Indian Railways system is thus more akin to the UIC system. UIC have of late moved away from the 'peak based' system to a

'statistical analysis based' system. This methodology is embodied in pamphlet UIC-518.

2. The basic features of the UIC-518 system consist of the following: Track is defined by standard deviation limits as QN1 (regularly planned maintenance), QN2 (requiring short-term maintenance) and QN3 (defined as 1.3 times the QN2 limits. This is the limit beyond which the track is not representative of usual quality standards). The prototype vehicle is run on about 50-100 km section. 25 sections of about 500-800 m length are chosen for statistical analysis purposes so that the following ratio is maintained – QN1:QN2: QN3 = 50%: 40%:10%.

   All quantities are statistically arrived at. Limiting values for statistically arrived at parameters are laid down.

3. Indian Railways should proceed in the direction of UIC-518 type statistical analysis based system in the following manner:

(i) Develop capabilities for digital data acquisition.

(ii) Develop the necessary software for statistical analysis.

(iii) Develop precise test track definition, preferably based on standard deviation values relatable to track maintenance requirements.

(iv) Run existing rolling stock of proven performance, collect data, statistically analyse it according to UIC-518 principles and arrive at limiting values of parameters applicable for Indian Railways.

(v) Rolling stocks of proven performance could be WDM2 locomotive, WAP4 locomotive, WAG7 locomotive, ICF coach and BOXN wagon.

8.6 Responsibility matrix

Activities	Rolling stock supplier	RDSO	Contractor	Operator
Tender Preparation/Technical specification		A	R	
Design	R	S		
Design approval		A	R	
Prototype manufacturing	R			
Test & Inspection plan	S	R, A	S	
Rolling stock preparation - Testing	S	S	R	S
Testing of Rolling stock	S	R	S	S
Final clearance		A	R	
Service operation	S	S	S	R
Maintenance Plan	S	A	R	
Maintenance	S			R

Table 20 Responsibility matrix in case of complete rolling stock

Activities	Component Supplier	RDSO	Contractor	Operator	Rolling stock supplier
Tender Preparation/Technical specification		A	R		
Design	S	S			R
Design approval		A	R		
Prototype manufacturing	S				R
Test & Inspection plan	S	R, A	S		S
Rolling stock preparation - Testing	S	S	R	S	S
Testing of Rolling stock	S	R	S	S	S
Final clearance		A	R		
Service operation	S	S	S	R	S
Maintenance Plan	S	A	R		S
Maintenance	S			R	S

Table 21 Responsibility matrix in case only components of rolling stock

Legend: R = Responsible, A = Approve, S = Support/Assist

Supplier: e.g. Alstom, Bombardier, Siemens etc.

RDSO: Research design and standards organisation

Contractor: DMRC, MRVC, RCF, ICF etc.

Operator: DMRC, Western railways, Central railways etc.

Complete RS (Rolling stock) Supplier: In case of partnership in awarded tender, e.g. Bogie by Supplier & Car body by ICF/RCF or vice versa.

8.7 Contractual considerations & further recommendations for systematic working with Indian Railways

1. Thorough study of the tender documents.
   - ✓ Bid queries shall be cleared before finalization of technical offer.
2. Technical offer needs to be given very clearly and specific clause by clause comments in detail.
   - ✓ Acceptance of all clause by clause comments in case agreed with the customer.
3. A realistic timeline including responsibilities of milestones for supplier and rolling stock purchaser.
   - ✓ Acceptance of milestones responsibilities by supplier and purchaser.
4. Definition of scope of supply including responsibility matrix during offer stage.
   - ✓ Including spares in case of complete rolling stock.
   - ✓ Including spares and interface parts in case of component supplier.
5. Standards and procedures to be used, needs to be defined during offer stage.
   - ✓ Detailed description of standards and procedures shall be applied for design, development and testing of rolling stock or components of rolling stock.
6. Design approval along with test & inspection plan with acceptance criteria and boundary conditions.
   - ✓ Complete design approval before go ahead for manufacturing the prototype components.
7. Component type testing.
   - ✓ Specifications & plan shall to be pre approved.
8. Rolling stock prototype building.
   - ✓ Go ahead shall be given by customer for prototype building.
   - ✓ Responsibility matrix shall be followed during prototype building.
9. Actual field testing.
   - ✓ All safety related approvals and test speed restrictions on the track of Indian railways shall be considered.
10. Acceptance of results by stake holders.
    - ✓ Methods for data measurement and data analysis shall be predefined.
11. Serial production shall be done only after clearance from IR.
    - ✓ Only after customer clearance for serial production, actual production shall be started.
12. Building & commissioning of rolling stock.
    - ✓ Site office of supplier shall be available in India for complete rolling stock or for components of rolling stock.
13. Start of service and warranty.
    - ✓ Maintenance plan and actual responsibility shall be predefined.

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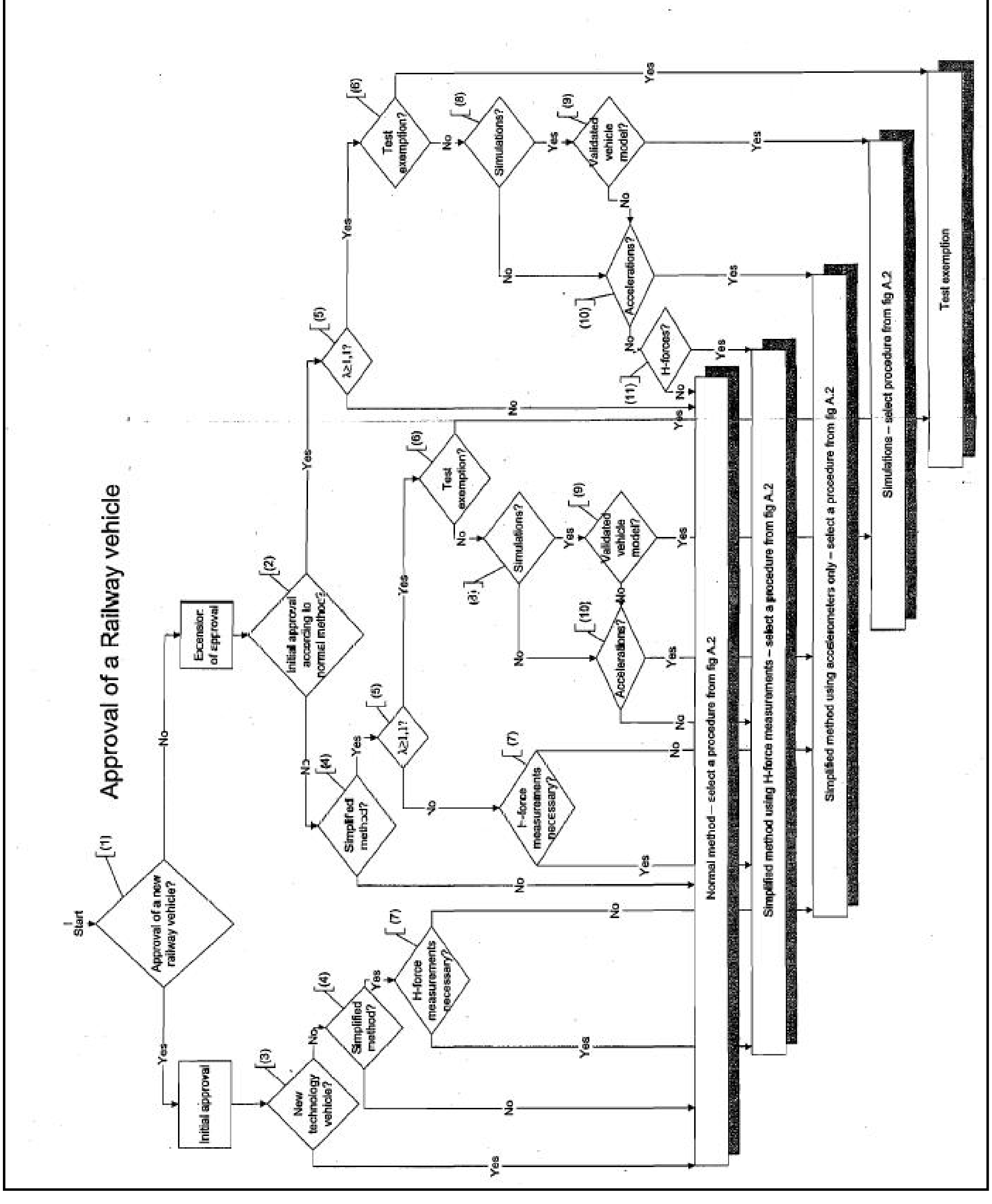
Appendix

Part 1 Approval of a railway vehicle …………………………………………………. II

Part 2 Abbreviations for calculations ……………………………………………… IV

Appendix, Part 1



(1) Does the matter concern approval of a new railway vehicle?

(2) Was the initial approval made using the normal measurement method (forces Y, Q...)?

(3) Is the vehicle a new-technology design (see point 5.2 - page 12)?

(4) Are the basic conditions for applying a simplified method (see point 5.3 - page 13) met?

(5) Was the λ factor calculated (see Appendix B - page 54) during the initial approval greater than or equal to 1,1?

(6) Are the conditions for waiving the tests (see Appendix B, first data column of the table corresponding to the type of vehicle) met?

(7) Are axle box force measurements required according to the specific requirements of point 5.3.1 - page 13?

(8) Are the conditions for using simulations (see Appendix B, second data column of the table corresponding to the type of vehicle) met?

(9) Is there a vehicle model, validated according to appendix K - page 90, available?

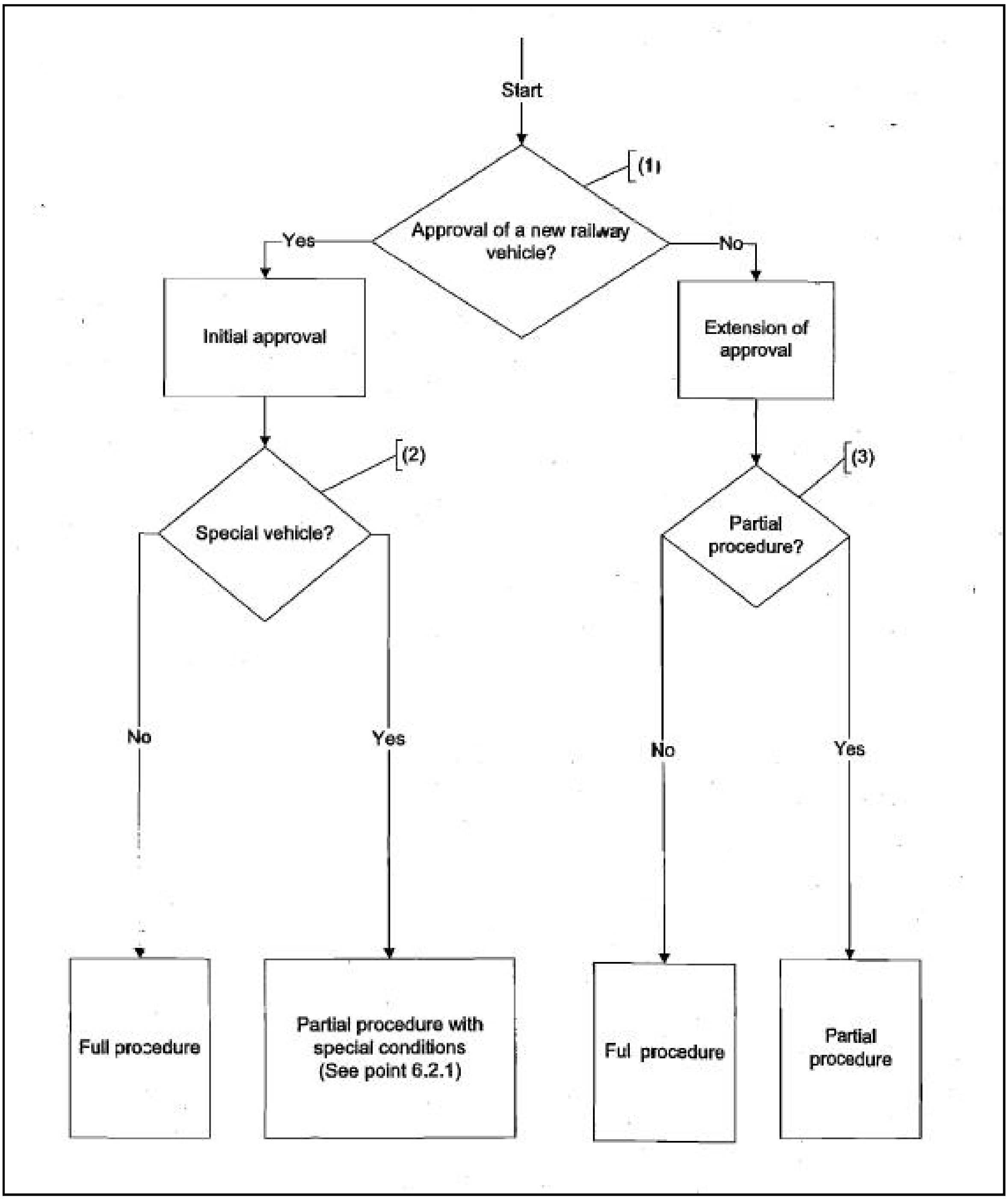
(10) Are the conditions for using a simplified method with acceleration measurements only (see Appendix B, third data column of the table corresponding to the type of vehicle) met?

(11) Are the conditions for using a simplified method with H-force measurements (see Appendix B, fourth data column of the table corresponding to the type of vehicle) met?

In case there is a concern in fulfilling the required test conditions and a vehicle model is available, validated according to Appendix K, the normal method as well as the simplified methods with or without H-force measurements may be combined with simulations (see point 5.4.3 - page 18).

In some cases where a vehicle has failed to pass a homologation test using the normal method and a vehicle model validated according to Appendix K is available, simulations may be used as a method to homologate the modified vehicle, (see point 5.4.1 - page 16).

Selection of assessment method



1. Does the matter concern approval of a new vehicle?
2. Is the vehicle to be tested regarded as a special vehicle?
3. The test cases marked in the right-hand part of the corresponding table must be carried out.

Appendix, Part 2

Parameter	Direction	Symbol	Unit
VEHICLE			
Guiding force Y			
Wheelset i, wheel j	lateral	Y_{ij}	kN
Force ΣY or H			
Wheelset i	lateral	ΣY_i or H_i	kN
Wheel force Q			
Static wheel load	vertical	Q_o	kN
Wheelset i, wheel j	vertical	Q_{ij}	kN
Wheelset i, side A wheel of vehicle	vertical	Q_{iA}	kN
Wheelset i, side B wheel of vehicle	vertical	Q_{iB}	kN
Other quantities derived from measured wheel forces			
Static axle-load	vertical	P_0	kN
Mean quotient lateral/vertical forces on inner rail	-	$(Y/Q)_{ir}$	-
Track loading force	-	B	kN
Overturning criterion	vertical	η	-
Accelerations on running gear $\ddot{y}$, $\ddot{y}^+$			
Assessment quantities for running safety			
Wheelset i (on wheelset 1, 2...)	lateral	$\ddot{y}_{s1}, \ddot{y}_{s2}$	m/s^2
Bogie frame, above wheelset i, wheel j	lateral	$\ddot{y}^+_{sij}$	m/s^2
Accelerations in vehicle body $\ddot{y}^*$, $\ddot{z}^*$			
Assessment quantities for running safety			
Vehicle body, above running gear I, II...	lateral	$\ddot{y}^*_{sI}$, $\ddot{y}^*_{sII}$	m/s^2
Vehicle body, above running gear I, II...	vertical	$\ddot{z}^*_{sI}$, $\ddot{z}^*_{sII}$	m/s^2
Assessment quantities for running behaviour			
Vehicle body, above running gear I, II...	lateral	$\ddot{y}^*_{qI}$, $\ddot{y}^*_{qII}$	m/s^2
Vehicle body, above running gear I, II...	vertical	$\ddot{z}^*_{qI}$, $\ddot{z}^*_{qII}$	m/s^2

Parameter	Direction	Symbol	Unit
Vehicle body, in the middle of vehicle 1, 2...	lateral	$\ddot{y}^*_{m1}$, $\ddot{y}^*_{m2}$	m/s^2
Vehicle body, in the middle of vehicle 1, 2...	vertical	$\ddot{z}^*_{m1}$, $\ddot{z}^*_{m2}$	m/s^2
OPERATING PARAMETERS			
Speed	-	V	Km/h
Cant deficiency	-	I	mm
TRACK			
Curve radius	-	R	m
Mean curve radius of the track sections of a zone	-	R_m	m
Vertical alignment	vertical	N_L	mm
Lateral alignment	lateral	D	mm
Gauge	lateral	E	mm
Twist	vertical/longitudinal	g_b	mm/m
Statistical parameters for track geometric quality	-	QN_i	mm
CONTACT GEOMETRY PARAMETERS			
Distance between contact points of the 2 wheels	lateral	e	mm
Lateral displacement of the wheelset	lateral	y	mm
Rolling radius of the wheel	-	r	mm
Difference of rolling radii between the 2 wheels	-	Δr	mm
Lower point of discontinuity in Δr-function	-	A^0	-
Upper point of discontinuity in Δr-function	-	A^{00}	-
Point for calculating the kinematically negotiable curve radius	-	E	-
Minimum curve radius with the possibility of kinematic rolling at point E	-	R_E	mm
Equivalent conicity	-	$\tan\gamma_e$	-
Radial steering index	-	q_E	-
OTHER SYMBOLS			
Number of track sections of a zone	-	$N\text{-}N_1\text{-}N_2$	-
Length of a track section	-	ℓ	m
Minimum length of the zone, encompassing all the sections	-	L	m
Instability frequency	-	f_0	Hz
Uncompensated lateral acceleration towards vehicle physical side A	lateral	-aq	m/s^2
Uncompensated lateral acceleration towards vehicle physical side B	lateral	+aq	m/s^2

Parameter	Direction	Symbol	Unit
Quotients considered for extension of acceptance	-	λ, λ'	-
Mass of the bogie	-	M_b	t
Centile corresponding to 50 % of the distribution function of a parameter on a given track section	-	$x_i(F_0)$	-
Centile corresponding to 0,15 % of the distribution function of a parameter on a given track section	-	$x_i(F_1)$	-
Centile corresponding to 99,85 % of the distribution function of a parameter on a given track section	-	$x_i(F_2)$	-
Statistical value of parameter x corresponding to frequency F_n of the distribution	-	$x\ (F_n)$	-
Mean value of parameter x	-	$\bar{x}$	-
Standard deviation for a parameter	-	s	-
Index i: for assessment quantities at track section i			
Index max: estimated maximum value of a parameter			
Index qst: quasi-static value of a parameter			
Index adm: permissible value of a parameter			
Index lim: limit value of a parameter			
Index m: for assessment quantities in the middle of the vehicle			
Index m up: for assessment quantities in the middle of the upper deck			
Index m down: for assessment quantities in the middle of the lower deck			
Index s: filtering of assessment quantities for running safety			
Index q: filtering of assessment quantities for running behaviour			
Index 2m: sliding mean over 2 metres of track			
Index initial: before modification			
Index final: after modification			
Index O/E/A°/A°°: values at point O/E/A°/A°°			

Declaration

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbstständig und nur unter Verwendung der angegebenen Literatur und Hilfsmittel angefertigt habe.

Stellen, die wörtlich oder sinngemäß aus Quellen entnommen wurden, sind als solche kenntlich gemacht.

Diese Arbeit wurde in gleicher oder ähnlicher Form noch keiner anderen Prüfungsbehörde vorgelegt.

Österreich - Graz, den 08. März 2014

Rajendra Dattatraya Devdare

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